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Book Review

TECHNOLOGICAL AND SCIENTIFIC DICTIONARY.—The object of the work is to furnish the modern signification of technical terms employed in the various arts and sciences, and by means of exhaustive articles to show clearly the principles and processes of pure and applied science. The numerous articles on the various branches of Chemistry, Theoretical, Practical, and Applied, as well as those of Mineralogy and Metallurgy, afford the latest information available, much of which appears here for the first time in any book of reference. By G. F. Goodchild, M. A. B. Sc. President of the Wadsworth Technical Institute, and C. F. Tweney, Late Librarian and Secretary of the Putney Public Library, of London, England. Philadelphia, J. B. Lippincott Company. Price $6.00.

THE ENGINEERING INDEX, VOLUME IV. 1901-1905.—An Engineering index covering the Technical Literature of the World. Edited by Mr. Henry Harrison Suplee, B. Sc., Member Am. Soc. M. E., Franklin Inst., etc., and J. H. Chuntz, C. E., M. E. Associate Editor THE ENGINEERING MAGAZINE. New York and London, The Engineering Magazine.

ELEMENTS OF SANITARY ENGINEERING.—By Mansfield Merriman, Professor of Civil Engineering in Lehigh University. Third Edition, Enlarged. New York: John Wiley & Sons. London, England: Chapman & Hall, Ltd. Cloth; 5¾ x 9¼ ins.; pp. 250; illustrated. $2, net.

HYDRAULIC TABLES.—Showing the Loss of Head Due to the Friction of Water Flowing in Pipes, Aqueducts, Sewers, etc., and the Discharge over Weirs. By Gardner S. Williams, M. Am. Soc. C. E., Professor of Civil, Sanitary and Hydraulic Engineering, University of Michigan, and Allen Hazen, M. Am. Soc. C. E. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. Cloth; 6 x 9¼ ins.; pp. 75; diagrams. $1.50

HYDROLOGY OF THE STATE OF NEW YORK.—By George W. Rafter. Bulletin 85, Economic Geology 12, New York State Museum. John M. Clarke, Director. Albany, N. Y.; New York State Education Department. Cloth; 6 x 9 ins.; pp. 902; 99 tables, five folding maps (two in pocket), 45 plates and 74 figures in the text. $1.50.

HANDBOOK OF COST DATA FOR CONTRACTORS AND ENGINEERS.—A Reference Book Giving Methods of Construction and Actual Costs of Materials and Labor on Numerous Engineering Works. By Halbert P. Gillette, Consulting Engineer, M. Am. Soc. C. E., M. Am. Inst. M. E., Late Associate Editor Engineering News. New York: Myron C. Clark. Morocco; 4¼ x 6¾ ins.; pp. 610; 30 figures in the text, and numerous tables. $4, net.

HYDROGRAPHIC SURVEYING.—Methods, Tables and Forms of Notes. By Samuel Hill Lea, M. Am. Soc. C. E. New York: The Engineerng News Publishing Co. Cloth; 6 x 9¼ ins.; pp. 172; 99 figures, mostly in the text. $2, net.

WATER SOFTENING AND TREATMENT.—Condensing Plant, Feed pumps and Heaters for Steam Users and Manufacturers. By William H. Booth, M. Am. Soc. C. E., Author of "Liquid Fuel and Its Combustion," "Smoke Prevention and Fuel Economy," "Steam Pipes; Their Design and Construction." New York: D. Van Nostrand Co. Cloth: 5½ x 8¾ ins.; pp. 308; 92 text illustrations and 42 tables. $2.50, net.

THE ANALYSIS AND SOFTENING OF BOILER FEED-WATER.—By Edmund Wehrenfennig, Mechanical Engineer, Chief Inspector of the Austrian Northwestern Railway in Vienna, in Collaboration with Fritz Wehrenfennig, Analytical Chemist, Director of Factories in Eggenberg. Translated by D. W. Patterson, M. E. Second Edition, Thoroughly Revised. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. Cloth; 5½ x 9¼ ins.; pp. 290; 171 figures in the text and two folding plates. $4, net; English price, 17s., net.

A PLUMBING CATECHISM.—Or, The Theory and Practice of Plumbing Design in Question and Answer. By Charles B. Ball, M. Am. Soc. C. E., and H. T. Sherriff, A. B., Editor of Domestic Engineering. Chicago, Ill.: Domestic Engineering. Cloth; 4½ x 6¾ ins.; pp. 100. $1.

MODERN TUNNEL PRACTICE.—Illustrated by Examples Taken from Actual Recent Work in the United States and Foreign Countries. By David McNeely Stauffer, M. Am. Soc. C. E., M. Inst. C. E., (Late) Vice-President Engineering News Publishing Co. New York: Engineering News Publishing Co. Cloth; 6½ x 9¾ ins.; pp. 314; 138 figures in the text. $3.50, net.

AMERICAN GAS LIGHT ASSOCIATION.—Report of Committee on Electrolysis, 1906. [A. G. Glasgow, London, Chairman; John Williamson, Chicago; S. P. Curtis, Philadelphia; Arthur H. Hall, New York. Prof. Albert F. Ganz, M. E., Consulting Engineer to Committee.] New York: The Association (George G. Ramsdell, Secy., 530 Broadway). Paper; 6½ x 9½ ins.; pp. 173; one folding plate and two text figures. 50 cts.

ICE FORMATION.—With Special Reference to Anchor-Ice and Frazil. By Howard T. Barnes, M. A. Sc., D. Sc., F. R. S. C., Associate Professor of Physics, McGill University, Montreal. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. Cloth; 5½ x 9¼ ins.; pp. 260; 40 illustrations, mostly in the text. $3.

VARIOUS WATER SUPPLY AND IRRIGATION PAPERS.—U. S. Geological Survey (Address, Director, U. S. Geological Survey, Washington, D. C.).

DICTIONARY OF ENGINEERING TERMS IN ENGLISH AND SPANISH.—With Indexes in both Languages; containing 3,000 technical terms with definitions. By Andres J. R. V. Garcia. New York, Spon and Chamberlain. Price $1.00, net

MECHANICAL DRAFT.—Contents, General Discussion. Systems of Mechanical Draft, etc.; Forced Draft. Closed Fire Room System, etc.; Induced Draft. Advantages, Disadvantages; Fuel and Air; weight of coal, evaporation, weight of air required, volume of air and gases; Draft, rate of combustion, resistance to, draft required under different conditions, etc. Economizers, effect of, proportion and cost. Fans, type and proportion of fans used. Proportioning the parts, diameter of fan wheel required, speed, power, size of engine, etc. New York, Spon and Chamberlain, 123 Liberty St., Price $2.00.

The following Books will be ready early in 1907:

THE VALUE OF PURE WATER.—By George C. Whipple. John Wiley & Sons, publishers, 43 East 19th St., New York, N. Y.

WATER WORKS MANAGEMENT AND MAINTENANCE.—By Hubbard and Kirsted. John Wiley & Sons, Publishers, 43 East 19th St., New York, N. Y.

DABNEY H. MAURY, President.

PAPERS PRESENTED

AT THE

TWENTY-SIXTH ANNUAL CONVENTION

OF THE

AMERICAN WATER WORKS ASSOCIATION

AND DISCUSSIONS ON THEM.

FILTRATION OF WATER.

The Element With Which We Have to Deal.

By F. A. W. Davis.

Water is composed of oxygen and hydrogen, oxygen by weight, 88.9, and by measure, 1; hydrogen, by weight, 11.1, and by measure, 2.

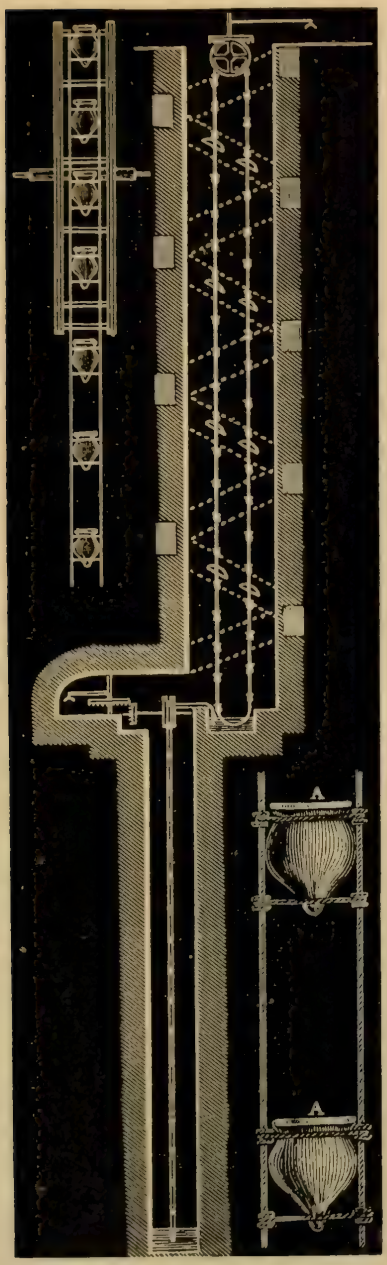
The primary source of the water supply is the clouds. Water rising from the earth in the form of vapor is changed to rain coming in contact with colder air. Falling on the earth in drops it replenishes the streams, lakes and ponds. A part of the rain percolates into the earth, replenishing subterranean waters, which in some localities rise to the surface, producing springs. In falling to the earth it is impregnated with the impurities of the air. In passing through the earth the water partakes of the elements of the soil, such as iron, sulphur, lime, magnesia and other elements. Surface waters are polluted in many ways, hence the necessity of filtration to purify them.

Again, as you are aware, wells are sunk in the earth, and water is raised to the surface by many devices.

History tells us of many efforts of nations long passed away, to obtain supplies of water. One of the most interesting accomplishments of the early ages is that of Joseph's well, in Egypt, which is still in existence.

This well is 24 feet by 18. The first section is excavated through rock 165 feet; the second section, and off to one side, is excavated 130 feet lower, until it reaches the gravel in which the water is found, the entire depth being 295 feet. A spiral passageway is cut through the rock around the well at a very gentle incline to lead the animals down to the intermediate basin. This passageway is 6 feet 4 inches wide, and 7 feet 2 inches high. Animals were used to drive the machinery that raised the water from the lower shaft into the reservoir basin and from the intermediate basin it was lifted in a similar manner to the surface.

Many wells and fountains made centuries ago, are living



JOSEPH'S WELL.

monuments of the existence of former nations, when buildings, monuments and statues have passed away.

When we recall that the human body is composed of about 83 per cent. of water, we should realize the importance of having plenty of wholesome water, and use it freely.

Ancient Efforts to Obtain a Supply of Water.

Water is one of the primary wants of human life, no less essential than air and food, hence the great interest that has always been attached to the procuring of it.

In the earliest records of civilization we read of the digging of wells and of quarrels about the possession of them. The "Pools of Solomon," near Bethlehem, which remain now almost as perfect as when they were built, were connected with a scheme for supplying Jerusalem with water.

In Assyria and Persia, from the earliest times, water has been conveyed to towns from long distances in open channels or canals, and in subterranean tunnels. In Egypt also, and in China, gigantic works for conveying water, both for domestic use and for irrigation, have been in existence from remote antiquity. We have evidence of the early existence of water works on the continent of America. The ancient city of Mexico, which was built on several islands near the shore of the lake, was connected with the main land by four great causeways or dikes, the remains of which still exist. One of these supported the wooden aqueduct of Chapultepec, which was constructed by Montezuma and destroyed by the Spaniards when they besieged the city. Hydraulic works on a great scale had also been executed by the Incas of Peru.

Of all the ancient nations, the Romans paid the greatest attention to the supply of water, and carried the construction of aqueducts to the greatest perfection and magnificence.

While it is not stated that our co-laborers in the work of supplying water, sold common water as distilled water or some noted spring water, I have, no doubt, that with their great wisdom they were worldly wise and turned a shekel as readily as some people of the present day turn a penny.

Note.—Since writing the above I saw published in a paper a statement that in excavating in the ancient city of St. Men-

ash, Egypt, they had found an advertisement saying, "Take Menash's Glorious Water and Pain Departs."

Purification of Water.

The Egyptians found that alum would subside turbid water, and so used it for that purpose. The Americans adopted alum in another form to settle sediment in the water and to entrap the bacteria. In some systems iron has been used, and still other substances for the same purpose. These processes are termed mechanical filtration. Another method of water purification is called the English or slow sand filtration, in which no coagulant is used. After years of study, the Indianapolis Water Company decided that of the two methods the latter was the better and surer in its results. Besides this, the local conditions were well adapted to slow sand filtration, by reason of the ownership of a portion of the Indiana Central Canal from Broad Ripple to the city of Indianapolis, about nine miles in length, the current being so moderate that much of the sediment is precipitated before reaching the filters.

White river is the principal source of supply, the water being impounded at Broad Ripple by a dam built by the State of Indiana and maintained by the Indianapolis Water Company.

The dam is 8 feet high and backs the water up the river about four miles. The comb of the dam is 32 feet above the low water in White river in the city. From this point the water is diverted to the head-gates of the canal.

From the head-gates the water flows through the canal (which was constructed by the State and from whom it was purchased) to the aqueduct over Fall Creek, and then to the intake house near the filter plant. Before entering the raw water line the water must pass through fine racks and sponges in the intake house, which keep trash and inhabitants of the water off the beds.

From the intake house the water flows through a 48-inch cast iron pipe line to the basement of the laboratory, where it flows upward through large cast iron cylinders having cages filled with sponges, and then on through the conduit by gravity to the filter beds.

There are arranged in the laboratory building a duplicate

set of centrifugal pumps, having a capacity of 20,000,000 gallons, that can pump water from Fall Creek whenever the water is out of the canal.

This gives the company three sources of supply, viz.: White river, Fall creek and its system of thirty, 8 and 10-inch wells with compressors furnishing 8,000 cubic feet of free air per minute, for lifting the water from the wells which are used in case of necessity.

The aqueduct, which it was necessary to construct to convey the water over Fall Creek, is 290 feet long, 36 feet broad and 5 feet deep, and is quite a fine structure.

This structure, and one in France, we believe, are the only ones of the kind made of concrete.

To the water company there were objections to some features of the construction of slow sand filter beds as ordinarily built. One was the open joint round underdrain tile. In this construction it is absolutely necessary for the water to flow from the center of the tile to the open joint. The tendency of the water to this common opening produces unequal drainage and coursing of the raw water, and the result is an unequal surface of the beds and not an altogether satisfactory effluent at all times. To avoid this difficulty we adopted a perforated tile having ⅝-inch openings.

There are about one million of these perforations in each of the filter beds, being spaced about 2½ inches apart over the entire bottom.

The arrangement of the filtering medium is practically the same as at other plants, viz.: one foot of graded gravel and 3 feet of fine sand. The sand that we used was taken from Fall Creek near the filter plant, and while not as uniform and fine as some cities have, our results have been equally as good if not better.

Construction of Beds.

The beds were originally 200 by 350 feet, and contained about 70,000 square feet. Since the original construction we have put in a division wall, making the area of each bed about 35,000 square feet. This was done so as not to have such large units out of service when cleaning, and to furnish a sup-

port for the roof. There was no other objection to the size of the bed. The filtration from the large bed was just as good as from the small bed.

The action of the wind and sunlight on water is unquestionably beneficial, but the sunlight causes vegetable growths which

View of the Aqueduct.

are very undesirable, and then again, the ice forms upon the beds in winter and makes it difficult and expensive to clean them. To avoid these troubles the beds were covered with 3-inch concrete and steel rods. Upon this cover is placed 2 feet of cinders.

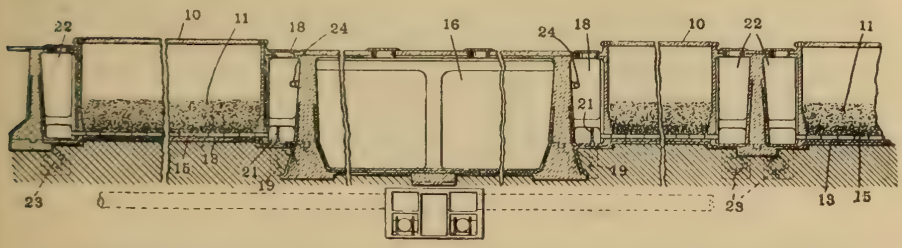
The supports of the roofs of the beds are 7-inch cast iron columns with flanges 8 inches apart of different depths so as to prevent the raw water from finding its way down the columns. The walls of the beds are stepped off for the same reason. The advantage of the columns, either iron or cement, is the saving of space in the beds over the groined arch. All

View of the Tile.

View Showing Tile Placed on Bottom of the Bed.

the walls of the beds and clear water basins are concrete with steel reinforcement. In the roof of the beds steel "I" beams were used, so we have both concrete and steel beams. However, the concrete are preferable. We find no advantage in the steel "I" beams, covered with cement, over the concrete beams reinforced with steel rods.

The bottom of the bed is made of 6-inch concrete laid upon rolled clay. On this is laid, in cement, the tile with perforated top, the joints being filled with cement. The tile are 2 feet long and 12 inches wide, with division walls making conduits 3 inches by 5 inches. The tile support the material forming the filter beds, and are laid end to end across the bed and through and into the baffle walls, forming the collecting gallery on the

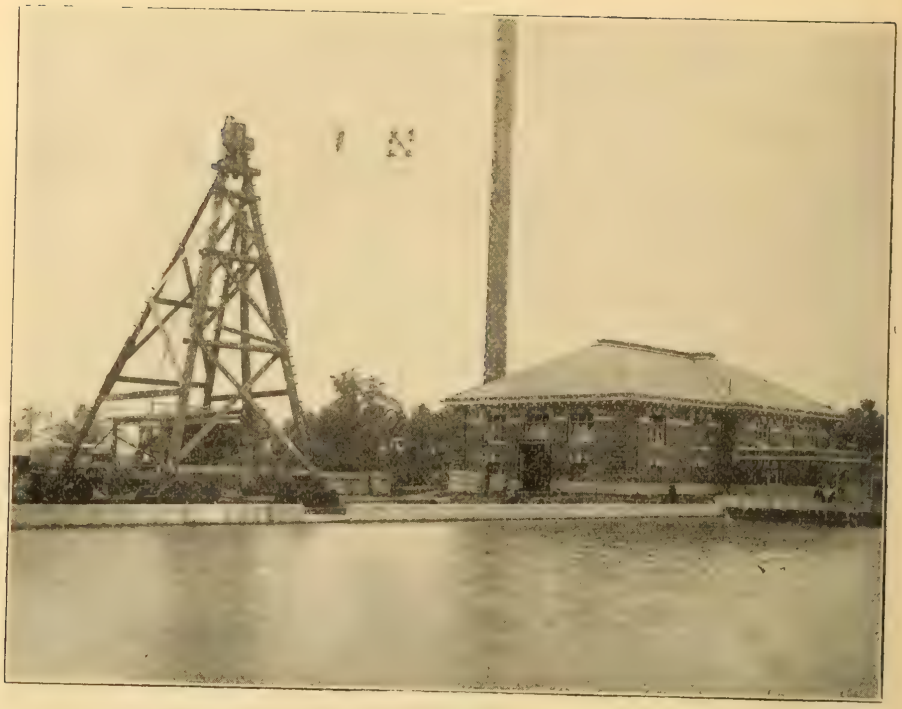


Cross-Section of Filter Bed, Showing Collecting Gallery, Washout Gallery, Clear Water Basin and Bed with Sand.

right, and the washout gallery on the left. Hose placed in the tile in the collecting gallery will force any sediment in the tile to the other side of the bed and into the washout gallery. These galleries have manholes, and, when the bed is drained for cleaning, they allow the air to pass under the bed and up through the gravel and sand. The galleries can be entered and the walls washed down and made sweet and clean. All parts of the underdrain system are accessible and easy of examination. The construction of the bed with the underdrain tile is an original feature, and, to our minds, a very great improvement over the round tile construction.

From this description you can readily understand that there must be uniform filtration from every portion of the bed without coursing.

The water flows from the collecting galleries into the clear



Open Filter, Showing Laboratory and Cableway.

View Showing Cover on Bed.

Construction View of Filter Cover.

Filter Bed

water storage basins through a 30-inch pipe which conveys it to the far end of the clear water basin, a distance of 300 feet, where it is discharged.

The purpose of conveying the water to the far end of the storage basins and then discharging it, is to keep the entire body in motion, thereby preventing any possibility of stagnation.

From the filter beds the water is taken through Venturi meters to the clear water basins. In the regulating houses, are all the latest devices for measuring the quantity of water discharged per day from each filter bed, showing the friction losses from day to day, and regulating the operation of the beds as to the rate of filtration. The regulating houses are connected with the clear water basins and the 48-inch conduit line leading to the Riverside pumping station.

The 48-inch conduit line is made of concrete reinforced with steel, and is nearly 6,000 feet long. From the conduit line the water is discharged by gravity into a receiving well from which suction mains are laid to the pumps.

The filter beds as constructed have an entrance at each end, each entrance serving for two beds and being located on the dividing walls. This arrangement proves very convenient for cleaning and recharging. The sand, when taken off the beds, is washed and stored in concrete bins, no other handling being necessary than the scraping of the beds. The scraped sand is transported by water under pressure by means of a portable Korting ejector and sand washer.

The sand on the beds is made as level as a floor, and, when the water is drawn off for cleaning, the surface of the bed is just as perfect as before the water was turned on. When filling the beds after cleaning, the filtered water from the clear water storage basin is introduced from below, through the perforated tile, and rises up evenly through the sand until the surface of the bed is covered to a depth of a few inches. Raw water is then turned on to the bed to a depth of 4½ feet above the sand, when filtration is started at a low rate per day until the effluent shows, by bacteriological examination, the water to be potable. The bed is then put into service at from three to four million gallons per day per acre. The water as it comes from the filter beds is bright and sparkling, as beautiful as

Interior of Clear Water Basin, Showing 30-inch Pipe.

Regulating House.

spring water, and of a high degree of purity. The beds, inlets, outlets, conduit and receiving wells are entirely free from odor.

The clear water basins are 70 by 350 feet, with a depth of 16 feet and 2 inches; capacity, 2,500,000 gallons. They are covered with a concrete roof which is supported by concrete columns and concrete girders reinforced with steel. Upon this roof was laid a track upon ties (rails weighing 70 pounds to

VALVES AND VENTURI METERS IN REGULATING HOUSE.

the yard) and as many as five dump cars, each hauling 3 yards, have been upon the roof at one time. The valves in the clear water basin are so arranged that water can be stored and the minimum or maximum amount taken out of the basin.

The laboratory consists of four rooms, a bacterial, chemical and general laboratory, and a reception room. The building is handsome and the arrangement very complete. The laboratories are equipped with everything necessary to make up-to date examinations of the water, and are in charge of a com-

Placing Sand on Filter Beds.

Sand Washing Machine.

petent and conscientious chemist and bacteriologist, who devotes his entire time to the study of the water supply. Daily examinations of water are made, samples being taken of raw and filtered water and the water from our mains. Below we give you a table of the results obtained from the beds during the first four months of 1906, with the cost of cleaning, but not putting the sand back on the beds. This period from January to May was selected because the raw water was turbid all the time on account of the dredging machine, which was being used to widen and deepen the canal. At times during this period the raw water was heavily laden with sediment from heavy rains and the spring thaws. Notwithstanding these conditions the results were highly satisfactory, as shown by the table.

SUMMARIES OF RESULTS.

OBTAINED FROM THE FILTER BEDS DURING THE FIRST FOUR MONTHS OF 1906.

TOTAL AMOUNT FILTERED 1906	Amount per Day	Hours Entire Plant Out of Service	Equivalent to % of Month	Making an Equivilant Filtration Rate Per			Avg. Cost of Cleaning	BACTERIA PER C. C.						Average Efficiency
								Influent			Effluent			
				Month	Day	Acre	Per Million Gals.	Highest	Lowest	Avg.	Highest	Lowest	Avg.	
January 261,180,000	8,420,000	48.5	6.5%	279,330,000	9,010,000	1,970,000	$0.59	74,000	1,600	8,445	950	3	51	99.4%
February 256,900,000	9,170,000	46.6	6.2%	273,870,000	9,780,000	2,130,000	.75	24,000	500	3,920	42	1	7	99.83
March 327,840,000	10,600,000	46.3	5.9%	348,390,000	11,240,000	2,430,000	92	69,000	900	10,000	1,000	1	56	99.44
April 247,110,000	8,200,000	59.6	8.3%	269,470,000	8,980,000	1,930,000	1.04	30,000	250	4,425	325	1	21	99.53
Average	9,108,000	50.25	7.7%		9,750,000	2,110,000	.875			6,697			34	99.55

There are times when the water is sterile, and we believe that we may yet be able to get a high rate of iltration and the effluent practically sterile.

MR. BAKER: Mr. Chairman and Gentlemen—As the papers have been distributed in advance, and mine among the number, I shall follow the statement made on the red book sent to us and allow the paper to be presented by title only, with the exception of giving a very brief outline of the theses which I have attempted to maintain.

My position in this paper is that, for water works men, where sewage pollution is involved the question is one of water purification rather than of sewage purification. I have in the course of the paper attempted to point out briefly how the real situation is improved, or at least might be made very much clearer, if we had better vital statistics than we have. I then proceed to outline briefly some of the methods of sewage purification that are available, and suggest the order in which they might be carried out. I have not gone into detail here, because it seems to me that without using a very great deal of space confusion would result and those not familiar with the subject might be very much misled. Any question of sewage purification or water purification must be worked out in accordance with local conditions. So I have attempted merely to outline some of the available methods of sewage treatment, and have added as an appendix to the paper a few definitions of processes. I have also given a brief bibliography or a list of books which bear on the subject in hand.

NOTES ON SEWAGE PURIFICATION AND PUBLIC WATER SUPPLIES.

By M. N. Baker, Associate Editor Engineering News.

Water purification, rather than sewage purification, unless both be employed, should be relied upon to protect water consumers from the dangers of sewage pollution. It is theoretically possible, but quite impracticable, to convert sewage into drinking water; or at least it is both cheaper and safer to purify diluted sewage, in the form of a contaminated water supply, than to purify the sewage itself.

If our vital statistics and also our records of the proximity of sewer outfalls and water intakes, together with relative volumes of sewage and water, were more perfect, the relations between water pollution and public health could be more accurately shown. As it is, we are largely dependent upon scanty and imperfect vital statistics, tardy and incomplete notifications of cases of typhoid fever, and we have practically no systematic studies of the effect of polluted water on causes of mortality other than typhoid, and very inadequate records of other causes for typhoid than polluted water. The pollution of our water supplies is known to exist but in only a few of our states is there much definite knowledge as to the nearness and volume of this pollution. In times of epidemics suspicions are cast upon public water supplies when other sources of infection, and particularly the milk supply, are the real cause of the outbreaks. It behooves water-works authorities to exert their influence to secure efficient boards of health, with proper registration of vital statistics, prompt notification, by physicians, of cases of typhoid fever and other communicable diseases, and equally prompt investigations by health officers of the origin of every case of communicable disease. By such means much unfounded criticism of the quality of public water supplies would be averted and just criticism, which every water-works man should welcome, would be possible and would often lead to needed improvements in our public water supplies.

As a partial consequence of the deficiencies and neglect noted in the preceding paragraph, no one dares specify the safe distance between a sewage outlet and a water-works intake, under conditions of no purification of either water or sewage, or of purification of the sewage only, or of the water only. If the dilution of the sewage be large the danger is, of course, lessened accordingly, regardless of distance involved, but it is by no means removed, even when the distance is many miles. With heavy dilution, with some miles between sewage outlet and water intake, and with adequate water purification, a large degree of safety is felt. The only safe general rule is to separate sewage outlet and water intake as widely as possible and to purify *all* surface water supplies. Where sewage is particularly threatening, either from proximity or relative volume, or both, and cannot be avoided, both the sewage and the water should be purified to the highest practicable degree.

As a rule, the object of existing sewage purification plants is to prevent offensive sights and smells, rather than to produce bacteria-free or bacteria-low effluents. It is possible, by low rates of intermittent sand filtration (a simple modification, at greatly reduced rates, of the well-known sand filtration of water), to produce sewage effluents low in bacterial contents—provided, of course, that suitable sand and land at low prices are available. In many, if not most, parts of the United States it will be found cheapest and best, if a high degree of sewage purification is required, to combine with intermittent filtration some preliminary treatment. The object of the preliminary processes is to reduce the organic matters in the sewage, and thus lessen the clogging of the sand filters; or, put another way, to make possible a higher rate of filtration on a given area. Probably the best preliminary treatment is afforded by either sedimentation or septic tanks, followed in some cases by either contact beds or percolating filters. At present the latter are most in favor and probably justly so. Where percolating filters receive sewage which has had a minimum of either sedimentation or septic treatment, it may be advisable to interpose sedimentation tanks of relatively small capacity between the percolating and the intermittent sand filters for the purpose of taking out the suspended matter that passes so readily through the large pores of percolating filters.

The less the previous treatment, obviously, the more of this matter there will be.

Broad irrigation has been used extensively abroad. Under favorable conditions it yields an effluent of low bacterial content. It has never been much used here and is not likely to be (except in the West, where every drop of water is needed for irrigation proper). It requires large areas of land, large forces of men and able farming and financial supervision. Like chemical precipitation, broad irrigation, where used, is giving way to or being supplemented by the rapid bacterial processes of sewage treatment.

Obviously, where it is believed that a high degree of bacterial purification is not necessary (as where the sewage works and water intake are far apart, or where the sewage is diverted into another drainage area, involving no public water supply) some of the other methods of treatment, or a simplification of the one just outlined, will suffice. The proposed plan, it will be seen, is really double filtration, possibly combined with sedimentation or septic tanks. Perhaps the mechanical filters so successfully used for purifying water might be substituted for a part of the combination of processes suggested. Both mechanical and slow sand filters, or double filtration, might also be used to purify a badly polluted water. The combination is in use at York and several other places in England.

I append to these notes some definitions or brief descriptions of the principal processes of sewage treatment in use. I also append a brief list of books and reports on both sewage and water purification.

DEFINITIONS OR BRIEF DESCRIPTIONS OF TYPICAL PROCESSES OF SEWAGE TREATMENT.

(Abbreviated from "British Sewage Works," by M. N. Baker.)

SCREENING.—This removes the coarser suspended matters by means of vertical or inclined bars, set with spaces between them, or else by means of a network of wire or metal rods. The screens may be cleaned by hand or by automatic rakes or brushes. Sometimes revolving screens, cleaned by fixed brushes, are used.

SEDIMENTATION.—Suspended matters are removed by affording an opportunity for them to be acted upon by gravity and carried to the bottom of a receptacle. If the time is so brief that only the heavy, mineral matters are deposited, the receptacle is called a catch pit, grit or detritus chamber. If the period is long enough to permit the deposit of lighter matters, the receptacle is called a settling or sedimentation tank or reservoir.

CHEMICAL PRECIPITATION.—Chemicals are used to assist or hasten sedimentation, thereby removing practically all the suspended

matter. The sludge, or matter thrown down, is greater in quantity than results with sedimentation alone, besides which the chemical used and the water taken up by it is added to the sludge. The sludge produced by sedimentation is frequently run onto land or onto filter beds, and left there for the water to drain and dry out. The same procedure may sometimes, although rarely, be adopted for the larger volume of sludge produced by chemical precipitation. As a rule, such sludge is made partially dry by means of filter-presses.

SEPTIC TANK.—Before the principles of bacterial action were known people marvelled at the number of years which a cesspool, built with open walls and in an open soil, could be left uncleaned, and yet never become filled with solid matter. A septic tank may be described as an elongated cesspool of far less relative capacity than the ordinary cesspool or as an enlarged settling tank, designed to retain solid organic matter until it has been more or less liquefied and gasified. The sewage flows in at one end and out at the other, commonly through submerged inlets and outlets. The tanks may be open or closed, according to local conditions. In the majority of septic tanks thus far built for municipalities the sludge must be removed at intervals of a year or less. A detritus tank is generally placed just ahead of the inlet to a septic tank, in order to retain mineral solids, which, of course, are not subject to liquefaction.

BROAD IRRIGATION OR SEWAGE FARMING.—We have here a combination of mechanical, biological and chemical action. The soil acts as a strainer, and at the same time affords a home for innumerable bacteria, which seize upon the organic matter in the sewage, transform it into plant food and gases, at the same time changing its chemical composition. The process is essentially one of oxidation and nitrification. The crops, dairy products or live stock produced on a sewage farm help reduce the cost of sewage treatment, but there is always a danger that the best sanitary results will be made secondary to the farming operations.

INTERMITTENT FILTRATION.—This is broad irrigation intensified, with the sacrifice of all, or nearly all, crops. In Great Britain the filtration areas are generally temporary, while in the United States they are permanent, and therefore constructed with more care and expense. In Great Britain intermittent filtration areas are generally merely portions of the most sandy or gravelly land available, while in the United States the intermittent filter beds are more or less artificial beds of sand, although often making use of material in its natural position. The sewage is applied to the beds at regular intervals, and flows onto and through them continuously until it is shut off. The beds then drain and rest. Meanwhile, a new supply of air, for the support of bacterial life, is drawn into the beds. In the United States such beds are constructed much like water filters, only without a layer of gravel at the bottom, and almost always with tile underdrains and with earth bottoms. The frequency of closing varies greatly with the size of the sand grains and the strength of the sewage.

CONTACT BEDS.—For these, coarse material is used, often placed in water-tight enclosures. The beds are filled with sewage, stand full, are emptied, and then stand empty. This operation is repeated from two to four times each 24 hours, with occasional longer periods of rest. The applied sewage generally receives prior treatment to reduce the matter in suspension, and, in some cases, to partially liquefy the solid organic matter. As a rule, the filtrate from a coarse-grained bed is applied to a bed composed of material of finer grain. The coarse beds are called primary and the fine beds secondary. The terms single contact beds and double contact beds are also used. The size of material for contact beds is sometimes as small as ¼ to 1 in. for the primary, and ¾ to 2 ins. for secondary beds. It may go beyond these extremes, more particularly in the case of secondary beds.

PERCOLATING FILTERS.—The essential features of percolating filters are that the method of applying the sewage and the size of the material are such that the sewage is continually percolating through the beds in the presence of and exposed to air. The sewage may be applied by means of sprinklers revolving in a horizontal plane, or by means of nozzles set in fixed pipes, or by means of perforated, fixed, open distributors. The object in any case is to effect a rain-like, even distribution of sewage over the whole surface of the bed. The material composing the bed is in large pieces, rarely less than, say, 3 ins. in greatest dimension, and sometimes as large as a man's head. The bottoms of such beds are water-tight, and are provided with channels for collecting the final effluent. The outer walls are laid as open as possible, either pigeon-hole style or of the material composing the beds, laid dry.

BOOKS AND REPORTS ON SEWAGE AND ON WATER PURIFICATION.

THE PURIFICATION OF SEWAGE.—Being a Brief Account of the Scientific Principles of Sewage Purification and Their Practical Application. By Sidney Barwise, M. D., B. Sc., Medical Officer of Health to the Derbyshire County Council. Second Edition, revised and enlarged, with an Appendix on the Analysis of Sewage and Sewage Effluents. New York: D. Van Nostrand Co., London: Crosby Lockwood & Son. Cloth; 6x9 ins.; pp. 220; folding and other plates, and text illustrations. $3.50, net.

SEWAGE AND THE BACTERIAL PURIFICATION OF SEWAGE.—By Samuel Rideal, D. Sc. (Lond.), Fellow of University College, London; Fellow of the Institute of Chemistry, of the Chemical Society, and of the Sanitary Institute of Great Britain, Vice-President of the Society of Public Analysts, Author of "Water and its Purification" and "Disinfection and Disinfectants." Second Edition. London: The Sanitary Publishing Co., Ltd. New York: John Wiley Sons. Cloth; 5½x9¼ ins.; pp. 308; 49 figures in the text. $3.50.

THE PURIFICATION OF SEWAGE AND WATER.—By W. J. Dibdin, F. I. C., F. C. S., formerly Chemist and Superintending Gas Examiner to the London County Council and the late Metropolitan Board of Works, from 1882 to 1897. Third Edition, revised and enlarged. London: The Sanitary Publishing Co., Ltd. New York: D. Van Nostrand Co. Cloth; 6x9 ins.; pp. 379; many tables, 27 plates and 16 figures in the text. $6.50.

TRADES WASTE: ITS TREATMENT AND UTILIZATION.—With Special Reference to the Prevention of River Pollution. By W. Naylor, Assoc. M. Inst. C. E., Chief Inspector of Rivers, Ribble Joint Committee. London: Chas. Griffin & Co. Philadelphia: J. B. Lippincott Co. Cloth; 7x9 ins.; pp. 267; tables, 48 plates, and many illustrations in the text.

SEWAGE DISPOSAL IN THE UNITED STATES.—By Geo. W. Rafter, M. Am. Soc. C. E., and M. N. Baker, Ph. B., C. E., Associate Editor, Engineering News. Second Edition. New York: D. Van Nostrand Co. London: Sampson Low, Marston & Co., Ltd. Cloth; 6¾x10¼ ins.; pp. 598; seven plates, 116 text illustrations and many tables. $6.

BRITISH SEWAGE WORKS—And Notes on the Sewage Farms of Paris and on Two German Works. By M. N. Baker, Ph. B., C. E., Associate Editor of Engineering News. New York: The Engineering News Publishing Co. Cloth; 6x9 ins.; pp. 149. $2.

THE TREATMENT OF SEPTIC SEWAGE.—By George W. Rafter, M. Am. Soc. C. E. No. 118, Van Nostrand Science Series. New York: D. Van Nostrand Co. Boards; 4x6 ins.; pp. 137. 50 cents.

SEWERAGE AND SEWAGE PURIFICATION.—By M. N. Baker, Ph. B., C. E., Associate Editor of Engineering News. Second Edition, revised and enlarged. New York: D. Van Nostrand Co. Boards; 3¾x6¼ ins.; pp. 153. 50 cents.

REPORT ON SEWAGE PURIFICATION AT COLUMBUS, OHIO.—Made to the Chief Engineer of the Board of Public Service by George A. Johnson, Engineer in Charge of the Sewage Testing Station. November 10, 1905. Columbus, O.: Board of Public Service (Henry Maetzel, Chief Engineer). Cloth; 6x9½ ins.; pp. 499; folding and other plates and many tables. Postage, 19 cents.

MASSACHUSETTS STATE BOARD OF HEALTH.—From 1890 to date. Boston, Mass.

THE FILTRATION OF PUBLIC WATER SUPPLIES.—By Allen Hazen, M. Am. Soc. C. E. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. Cloth; 6x9 ins.; 448; tables, plates and 35 text illustrations. $3.

WATER FILTRATION WORKS.—By James H. Fuertes, M. Am. Soc. C. E. New York: John Wiley & Sons. Cloth; 5x8 ins.; pp. xviii + 283; 45 figures and 20 half-tone plates. $2.50.

WATER SUPPLY.—(Considered Principally from a Sanitary Standpoint). By William P. Mason, Professor of Chemistry, Rensselaer Polytechnic Institute. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. Cloth; 6x9 ins.; pp. 448; illustrated. $4.

THE PURIFICATION OF PUBLIC WATER SUPPLIES.—By John W. Hill, M. Am. Soc. C. E. New York: D. Van Nostrand Co. Cloth; 6x9¼ ins.; pp. 304; tables, and 32 figures in the text. $3.

POTABLE WATER AND METHODS OF DETECTING IMPURITIES.—By M. N. Baker, Ph. B., C. E. New York: D. Van Nostrand Co. Boards; 4x6 ins.; pp. 97. 50 cents.

REPORT ON THE INVESTIGATIONS INTO THE PURIFICATION OF THE OHIO RIVER WATER AT LOUISVILLE, KENTUCKY.—By George W. Fuller, Chief Chemist and Bacteriologist to the Louisville Water Co. New York: D. Van Nostrand Co. Cloth; 9½x12 ins.; pp. 461; tables, and eight plates. $10.

The official reports on water purification at Pittsburg, Cincinnati, Washington and New Orleans may also be consulted with profit.

Unfortunately there is no recent comprehensive American book on sewage treatment. The first four books on the list are by British authors, but the first three of them describe and discuss the rapid bacterial processes now so much in vogue, particularly in Great Britain. "Sewage Disposal in the United States," was written before the rapid bacterial processes came into use. The Columbus report on sewage purification contains much valuable matter, some of which bears on the possibilities of obtaining a high degree of bacterial purity.

Discussion.

Mr. Dunham (by letter): This valuable paper was read by title or so modestly by brief synopsis as to attract but little attention. It will be read and used often for reference. A list of books as usually advertised is well worth perusal, but the comparative merit of any list furnished by the author of this paper lies in the fact that its value has been determined by his experienced judgment and whatever is recorded of new or experimental work comes from such accurate and trustworthy investigators that it can be depended upon and satisfactorily repeated anywhere. In clear contrast to the value of such knowledge there might be mentioned a tendency—possibly a growing tendency—in the conventions to attempt to settle various questions by aid of legal decisions from different parts of the country. Many decisions are of real interest and law like physics, has its principles, but these legal principles are so warped and modified by "local practice" of attorneys and want of practice by juries that it can be safely asserted there is but a slight chance a decision in one State would be repeated in another or even in another county in the same State, with evidence precisely the same, and of course it never is. When a plain, common-sense view does not prevail there is little satisfaction to be had except in trying out the particular case in the particular court where it belongs. But the recommended books embody the best of modern methods and valuable results from various parts of the world. If they were studied and used with discernment there would be fewer legal contests. If the author of the paper can be persuaded to furnish each year a similar review and guide to current publications, he will do the association a favor that will be gratefully and increasingly appreciated.

Dr. W. P. Mason: Mr. Baker's contention that "water purification, rather than sewage purification, should be relied upon to protect water consumers from the dangers of sewage pollution" meets my hearty endorsement. Elsewhere I have held, and it is still my opinion, that a land should be looked upon as watered by its smaller lakes, its openings and its brooks, and sewered by its great, especially its navigable rivers.

The up-stream city, situated upon some great tidal estuary, might well complain, should it be forced, at great expense, to establish a sewage-disposal plant, when the town below, for the same or less money could purify the polluted water or else secure a superior supply from another source.

May I add one word to the suggestion that water works authorities should exert themselves to secure efficient boards of health. In a recent report I strongly urged the city authorities to make use of the services of the local country physicians as board of health deputies, whose duty should be to guard the watershed against rural pollution. Such men could be secured at small salary, and their knowledge of the whereabouts of cases of disease and their professional ability to ward off danger from the same would go far towards diminishing the risk attending the use of unpurified surface water. Mr. Baker says *all* surface water should be purified. As a general statement this is true, and it is the end toward which we are tending, not only because of the sanitary results secured thereby, but also because the public is now demanding a good looking water as well as a wholesome one. For a long time yet, however, raw surface waters will be employed in certain localities, and I earnestly advance the proposition that the country doctor will prove a most efficient employee of the city board of health.

Mr. George W. Rafter (by letter):

Mr. Baker refers to the indefiniteness in vital statistics, making the following statement:

> We have practically no systematic studies of the effect of polluted water on causes of mortality other than typhoid, and very inadequate records of other causes for typhoid than polluted water.

The writer agrees, and goes further in this that such indefiniteness is a disgrace to our so-called civilization. In our large towns as well as in most of the States, the health departments are so permeated with politics as to be absolutely ineffective, growing worse from year to year, so that without being at all pessimistic the writer can see little prospect of improvement. In the small towns and in the country, there is occasionally an honest man trying to do his duty, but he is so hemmed about by local politicians as to negative every effort.

This condition is serious, and it is not strange that some one cause should be hit upon and reiterated as the primal one of polluted water supplies. Undoubtedly, the most important of these is the view that typhoid epidemics are due to water-borne typhoid, alone.

Aside from the investigations of the Typhoid Fever Commission for the Spanish War of 1898, there is relatively little literature in this country pointing out that there are a number of other sources of typhoid fever, although the real fact is that in addition to impure water, there are a great many other sources, such as the use of infected milk, uncooked oysters which have fattened in typhoid infected waters, infection from personal contact, the use without disinfection of infected clothing, the agency of flies, mosquitoes and other insects, the use of uncooked vegetables which have been washed in polluted water, etc. Typhoid fever may also be spread by air currents, as in the case at the State Prison at Jackson, Michigan.

The theory of Pettenkofer is another view as to the spread of typhoid fever which was formulated over thirty years ago, and for a time received a great deal of attention from scientific men, although recently less is heard of it, chiefly because it has been overshadowed by the polluted water theory of typhoid. Lately, however, it has come into somewhat more prominence and in 1898, Dr. Christopher Childs, an English investigator, visited Munich in order to satisfy himself as to all the conditions and as to the present status of Pettenkofer's views, there. In a paper on The History of Typhoid Fever in Munich, read before the Epidemological Society of England in 1899, Dr. Childs reviews the evidence, reaching these conclusions:

(1). Drinking water has not played an important part in producing and reducing typhoid fever epidemics in Munich.

(2). The great prevalence of typhoid fever in Munich was due to pollution of the soil, correlated with movements of the subsoil water.

(3). The reduction of typhoid fever in Munich was due to gradual purification of the soil.

It is evident, then, that as recently as 1898, the views of Pettenkofer were materially strengthened by the investiga-

tions of this English physician, and we may conclude, therefore, that the real fact is that the source of typhoid, instead of being confined chiefly to impure drinking water, is complicated—that there are, in fact, several distinct causes for the production of typhoid fever.

While the foregoing is fundamental, nevertheless the statement of Mr. Baker that no one dares specify the safe distance between a sewage outlet and a water works intake, is equally true and one of the not very satisfactory signs of the times is a disposition on the part of engineers to reduce this distance. The writer feels sure there are a number of things which the gentlemen with this attitude have overlooked, among which he will cite the dictum of the English Rivers Pollution Commission, written in 1874:

Although the flow of a river has but little effect in purifying the water by the oxidation of the dissolved organic matters, it has a most material influence in the removal by subsidence of a large proportion of the suspended impurities, both organic and mineral, especially if the flow be sluggish in places. In passing through still pools, the turbid stream lets fall its load of grosser, mechanically suspended particles, and thus the water becomes clearer, although the dissolved impurities remain nearly as great as ever. It is doubtless this clarification by subsidence which has led to the very general, but erroneous, belief in the rapid self-purifying power of running water. * * * * * Assuming that if the polluted water had been constantly exposed to the air, a portion at least of the oxygen used would have been replaced, and assuming further that the oxidation proceeded during 168 hours at the maximum rate observed (during which time the stream flowed 168 miles), then at the end of that time only 62 per cent. of the sewage would be oxidized. * * * * * It will be safe to infer from the above results that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.

A number of determinations on the longevity of the typhoid bacillus in polluted water have been made which support the preceding view. These statements of the Rivers Pollution Commission were written thirty-two years ago and they are as sound to-day as when written.

RIVER POLLUTION.

A Discussion of Its Present Status and Suggestions Concerning Remedial Policy.

By Marshall O. Leighton, U. S. Geological Survey.

River pollution, like many other present day abuses, is one of the consequences of human progress and a result of the improvidence arising from rapid civic and industrial development. Few great reforms or progressive measures have been successfully exploited without at the same time bringing into prominence a covey of attendant disadvantages, and the ultimate value of any such reform or measure is generally determined by the margin of benefit which it confers over and above the united force of these attendant disadvantages. We have then the development of society from the pastoral to the civic state accompanied by benefits and blessings too obvious and too manifold to be recounted here. Beside these towering things, crouch a few parasitic disadvantages, the greatest of which is river pollution.

It cannot be said that man is entirely blameworthy for the present conditions of stream pollution. His life processes and his domestic economy involve the production of wastes of which he is obliged to dispose. In seeking for a place of disposal he is everywhere reminded that all nature uses the water carriage system. Thus, with nature's necessities imposed and nature's methods of disposal clearly set forth as an example it is not surprising that our streams are polluted. The matter becomes a subject for correction by some means, but it should be borne in mind that in the selection of these means the necessities imposed by nature should be taken into account and the importance of stream pollution should always be considered subordinate to that of social and industrial development. Remedial measures that do not take this into account must fail.

There are certain conditions and premises with reference to river pollution that are far beyond the control of mankind, and therefore not subject to remedy, legislative or otherwise. It will be helpful to review these and to determine just how far we are helpless, and at what point we may helpfully intrude. The water that flows in a river channel is largely derived from

the land lying within its drainage basin. The rain falls upon the ground and either runs off directly into water courses or sinks into the ground to reappear sooner or later either in the form of springs or as seepage, so that ultimately all the rainfall, except that which evaporates, finds its way into the river channels. Now, it is well known that water is an excellent solvent. As it passes over or through the ground it dissolves larger or smaller quantities of those materials with which it comes in contact. If it passes through a bed of salt, for example, it will, when it emerges, contain some of that salt, or if it encounters filthy conditions it will contain an abnormal amount of organic matter. So it is that the ingredients contained in a water afford a fairly faithful record of the conditions over or through which that water has passed.

We are accustomed to believe that a water draining a primival area is unpolluted or normal. By this we mean that the water in passing over or through the ground has encountered no organic contamination of human origin and therefore it contains nothing of a disease producing character. When, however, man takes up his abode upon this drainage area there comes of necessity a change. The water passing over or through this inhabited land must acquire characteristics that it hitherto did not possess. It now picks up and dissolves wastes of human origin and just here begins that process of pollution, slow and negligible at first, but increasing step by step with the growth of population upon the drainage basin, until we have at last the typically polluted condition of a river familiar to every observant man. Two distinct types of pollution may here be distinguished: First, and most obvious, that which is turned into the river through specially constructed conduits such as city sewage and industrial wastes; second, the natural drainage of occupied land that begins with the occupation of the first settler, increases with the population and persists as long as the basin remains inhabited. Let us discuss the latter.

It will be admitted at the outset that such pollution is inevitable. So long as the law of gravitation persists, rivers draining occupied lands must be polluted. The under-drainage of cities and the street washings, entirely aside from municipal sewage, are impure and their discharge into streams will

defeat all measures to restore any river to its pristine purity. In addition to such polluted drainage, there are those occasional and oft times surreptitious pollutions which seem of necessity to occur wherever people live along the banks of a stream, or have access thereto; until the millennium is realized, such pollutions will prevail.

It may be claimed with some degree of confidence that the pollutions above described are insignificant, and in the majority of cases have no bearing upon the great problem. This is true in a measure only—if we review the history of the startling typhoid fever epidemics of the United States, we shall find that many of them had their origin in just such apparently insignificant pollutions as those mentioned. Plymouth, New Haven, Ithaca and Butler are excellent examples of the effects of such pollution and it is worthy of note that the great epidemics of Lowell and Lawrence were not caused directly by the sewage of Manchester, Concord and other cities above on the drainage basin, but by an incidental pollution of Stony Brook. Of course, it is not claimed that such pollutions are the prime cause of typhoid fever in the United States—the steady grind of typhoid in our cities is far more serious than the explosive outbreaks of the character above mentioned, but it is from these outbreaks that we have received the most complete confirmation of our ideas of typhoid transmission, and they do emphasize the importance of isolated and apparently insignificant sources of infection. It is obviously impossible to determine whether any or all of the residual typhoid fever in cities using surface waters is caused by the polluted drainage of occupied land. We know, however, that the specific germs of this disease persist in the ground and we know from analogy that they must be washed out along with surface drainage. Further, we can be sure that having been so dislodged they can be transmitted over long distances in water courses, even as can those introduced more directly from sewers. That their virulence may be impaired is probable, but it hardly seems necessary to state that the bitter experience of many communities has demonstrated that it is unsafe to depend upon impaired virulence as a safeguard against typhoid fever.

There is, then, an inevitable pollution which must be ac-

cepted and which seems to present a basis for remedial efforts. Instead of determining the degree of pollution of a stream by comparing its conditions with those of a pure stream, it will be altogether better to accept the inevitable and to declare that, inasmuch as the river draining inhabited countries must be polluted to a certain extent, no person shall be regarded as amenable to anti-pollution laws who does not impair the value of that stream beyond that at which it is necessarily impaired. Let us consider just what this means. The inevitable pollution of a stream is reasonable; it never reduces a river to a stream of liquid filth, never discolors the water or renders it abnormally turbid; it does not change for the worse its availability for use in industries, does not increase its scale forming, corroding or foaming ingredients, nor does it kill fish nor in any way damage the water as a resource except in one respect, namely, its use as a domestic water supply. Water so polluted is unfit for domestic consumption in its raw state. Here we meet a far-reaching damage, but one which nevertheless is unpreventable. It must be accepted and regarded as a part of the price which society must pay in exchange for the advantages derived from the social settlement of the drainage area. There is involved here the acceptance of the hypothesis which has of late been borne more and more upon the minds of thoughtful men, namely, that no running stream upon the drainage area of which there is unrestricted social and economic intercourse is fit for use as a domestic water supply in its raw state. Cities in this country must in the majority of cases take their supplies from rivers flowing by their doors, must take them as they come down in their inevitably polluted condition. Some form of purification must be the resort.

If it be agreed that the premises outlined above are correct, or in other words if we accept—as we are bound to accept—a certain reasonable pollution on streams we will have designated a comprehensive boundary between that which is permissible and that which should be prohibited by law. Under such an interpretation, anti-pollution laws would be reasonable and logical and, what is equally important, susceptible of enforcement. An act of pollution that affects only the domestic water supply values of a river but which does not render the water so foul that it cannot be readily purified by reasonable and

economical methods does not change the status of a stream draining an inhabited basin. No claim for alleged damages arising from such an act can be sustained. Just here comes a suggestion of the reasonable degree of purification to be demanded of sewage disposal plants.

In the early days of sewage purification, the consummate expectation was that some day the processes might be so perfected that sewage effluents would be potable. Indeed, certain experimental results gave such promise, but it was soon found that municipal plants operated upon a practical basis could not be made to produce a constantly pure effluent however skillful and faithful those in charge might be. Possibly it is as well that they cannot. There are, of course, certain situations in which it would be desirable to produce a sterile effluent, but in the enormous preponderance of cases such an effluent would be far better than the stream into which it was discharged. Therefore, it is contended that the limit of purity demanded of a sewage effluent is that set by the inevitably polluted condition of the river, or, in other words, an effluent should not render the water of the stream impossible to purify for domestic purposes by filtration or some similar and economical means. The author believes that the best index of required purity of sewage effluents is that of putrescibility. If an effluent contains intestinal bacteria, it is on a par with the water of the stream into which it is poured and should not be complained of. If, on the other hand, it does not contain sufficient oxygen to complete the mineralization of its own organic matter, or in other words, if it is putrescible, it is inferior to the river water, and should not be tolerated.

Our attitude with reference to the wholesale discharge of sewage and industrial wastes from cities and manufacturing plants must differ widely from that above suggested. Here, we encounter a wanton abuse that damages every resource vested in a stream, and in the end renders the water unfit even for purification. Corrective measures are demanded and with this demand arises the most of our difficulties. Success depends largely upon the methods of campaign, and it is not assured by the fact that the cause is just. In the present state of society justice is generally a less efficient weapon than policy. However much we may deplore the condition, we cannot shut

our eyes to the fact. Why not make use of it?

If we review the history of social progress, we shall find that it has always proceeded in a well defined, natural order. It has taken its initiative from some material desire or need, or, in other words, from something based upon the desire for comfort, wealth, or power. After the material considerations come the intellectual and moral; the function of the second is that of adapting means to an end and the third is merely the product of the first two. This is true even in the acquisitions of science and art. While they have been primarily the result of intellectual forces, they have never contributed to social progress until material considerations have forced their adoption. The art of printing, for example, lay dormant for thousands of years before material demands became such as to allow it to exert an influence.

Now, the abolishment of stream pollution will be the result of social progress, and it must take the same historic course. Therefore, when we attempt to lead the world to such a reform by way of intellectual or moral routes we are beginning at the wrong end. In other words, we must make the desire for the abolishment of stream pollution a material demand. It needs only a cursory glance over the history of health legislation and sanitary enforcement to show how barren of results has been the plea for improvement founded upon consideration of sickness and death. Such a plea makes no impression upon the average legislator, and it moves him to action only when the accumulation of dead bodies and the loss of wages due to sickness result in a reduction of trade or an injury to some business interest. It was necessary for Pittsburg to become the foulest incubator of typhoid fever in the United States before a decent water supply could be secured. Philadelphia, Washington, Chicago, Louisville, Cincinnati, and many other places have found it necessary to become disreputable before they were permitted to become penitent. Therefore, the author believes that if we would abolish the wanton pollution of streams, we must enter upon a campaign with a dollar sign for the standard. We must disregard the suffering, leave behind the graves, and be quite mercenary. A basis of presentation like the following is suggested:

There are many reasons why anti-pollution legislation is

necessary to social and economic integrity; there are many more reasons why it is justified by dire necessity, both current and future. Such legislation is one of the inevitable consequences of civic and industrial growth and it has been the resort to which the populous and enlightened countries of Europe have been driven.

There is no necessity of mankind save one more acute than that for water. It must be provided in sufficient amount and of pure quality. While mankind was in the pastoral state neither of these requirements became assertive, but in the present state of urban development, they are satisfied only by the highest degree of engineering specialization. In its most serious phases, the task of supplying water in quantities sufficient to meet the most exacting municipal demands involves the ingenious adaptation of available resources to controlling conditions. By reason of an improvident public policy, the task of securing water of suitable quality is in many sections of the country fast becoming a tax upon human ingenuity because the resources are continuously subject to greater and greater damage and because the controlling conditions are approaching the impossible.

The great sources of municipal water supply must be the running streams. While it is true that certain favored cities are situated sufficiently close to upland drainage areas to make it economically possible to establish protected conservancy systems, by far the greater number of municipalities in the United States cannot, without entirely disproportionate expense, be served in this way. Neither is it possible to serve large cities with ground water. There are comparatively few places where the underflow occurs in sufficient amount to satisfy the enormous and increasing demands of a large city, and in such places it is too frequently the case that the water is too hard to be used with satisfaction for domestic and industrial purposes. It is also true that, however abundant a ground water may appear to be at first, there is always a limit to the amount which may finally be drawn. The supposedly inexhaustible supplies of ground water may be impoverished as certainly as may be the rain barrel at the back door of a primitive farm house. In either case it is simply a matter of excessive demand. This principle has been abundantly demonstrated in many American

cities. Therefore, it may be accepted as axiomatic that the great and ultimate source of municipal water supplies must be the rivers. Cities must take the water as it passes their doors and moreover they must take it in the condition in which it comes down to them.

The demand that the water of a river shall be preserved in a comparatively pure state is not merely esthetical. On the contrary, it is practical and vital and enters into the economy of a nation more acutely than almost any other resource. It demands consideration from the pecuniary standpoint. The wanton pollution of our streams is as improvident as the wanton destruction of forests or the extermination of cattle. There is no modern business law, no competitive commercial policy that does not apply as acutely to stream pollution as to any other vested resource. The whole matter may be comprehensively reviewed by relating three fundamental facts: First, we must have pure water to secure the perpetuation of the race, to maintain our industries and to preserve our fish; second, those who live in cities must in the majority of cases take the water which flows by in rivers; third, the contamination of those very rivers is increasing at a rate which is rendering it difficult in many places to find water adaptable for domestic or industrial purposes in its raw state, and there are not a few places where the amount of polluting matter has increased to such an extent that it is difficult or impossible to purify the water by filtration.

The most serious factor of stream pollution in the United States is that it is increasing, and unless remedial measures are enforced, such increase must continue at a rate that will keep pace with civic and industrial growth. The pecuniary damage which has been wrought during the past decade by this wasteful practice should be a most forceful warning concerning the future. The crucial period is not remote; on the contrary, there are many parts of our country in which the conditions are like those which prevailed in Europe a half century ago. European countries were obliged to adopt remedial measures, and similar action upon the part of the United States is inevitable; there is no alternative. The pertinent question is therefore an economical one, namely, shall stream pollution be regulated now while there yet remains some meas-

ure of purity in many of our streams and while corrective legislation may be applied gradually and without hardship, or shall action be postponed until our rivers are reduced to an unspeakable condition and summary measures will be required. In the one case, correction will be easy and comparatively inexpensive, while in the other it will be difficult and the cost will be enormous.

In considering the proper character of legislation, it should be borne in mind that all progress is gradual and that it will be necessary at first to accept and enforce a statute which will not be ideal but which will be considered merely as a step in advance. Such a law will work out its own justification, and the benefits which it confers will be so apparent that it can without opposition be gradually and judiciously amended until it becomes ideal in its form. Such a law should guarantee an impartial and considerate hearing to those believed to be in violation of its initial provisions; it should provide reasonable standards and it should be no offense against such a law if it can be shown that the polluting matter complies with such standards. Consideration should be made of the fact that there are many wastes, especially industrial wastes, concerning which we know little or nothing and for which no methods of purification have been provided. Therefore, it should be provided that no person shall be considered in violation of the law so long as such person may show that he is using the best practicable and available means of purifying such matter before it is conveyed into the stream. The damage caused by such obscure wastes in many cases represents but a poor price in payment for the social and economic development conferred upon the community by the maintenance of the offending municipality or industry.

The following is suggested as a schedule defining the character of polluting substances that should be proscribed by statute:

Any liquid which contains a greater number of parts by weight of suspended matter, or of the salts of calcium, magnesium, iron, sodium and potassium, than that normally carried by the rivers in the country immediately surrounding, or any liquid possessing an acidity greater than that which would be produced by adding twenty parts of standard chemically pure

hydrochloric acid, to one million parts of distilled water, except in cases where it can be shown that greater amounts of suspended matter or of said salts or a greater degree of acidity does not create damage to natural waters.

Any liquid which contains a greater proportion of metallic arsenic than 0.1 parts in one million parts of water.

Any liquid which contains a greater proportion of metals or metallic salts other than those herein specified, than 20 parts in one million parts of water.

Any substance which becomes putrescible after incubation for one day at 37° Centigrade, the index of such putrescibility after such period being an insufficiency in the amount of oxygen free or in organic combination in such incubated sample to combine in stable form with all organic carbon and nitrogen present.

Finally, it is believed that a concerted effort should be made to secure the passage of an act in Congress prohibiting the pollution of interstate waters, or, if such is believed to be unconstitutional, an effort should be made to secure the passage in each state of a joint act. This would, indeed, be a gigantic task, but well worth the effort. A glance over the country will show that interstate waters are the ones which require the most immediate action. The correction of such abuses within a single state is well nigh futile if that state remains practically helpless in the matter of interstate pollution. A common authority over such waters appears to be the only logical solution. There should be a provision for the appointment of a commission similar to the Rivers Pollution Commission of England, which shall have charge of the enforcement of the act, and upon which shall be conferred certain administrative and quasi-judicial powers designed to insure expedient and equitable procedure, from the decisions of which there shall be provision made for appeal even to the United States Supreme Court.

Finally, and most important, it should be recognized in such act that streams must receive a certain amount of pollution and only the improvident and unreasonable practices should be subject to correction.

MR. LEIGHTON: In conclusion, gentlemen, I would like to call your attention particularly to the hydrographic investigations being carried on by the Federal government, the main purpose being to assist those interested in water supply resources. They include the determination of those resources from all standpoints. For some twelve years the government has been carrying on this work, and while in many cases there has been shown an appreciation of it, it has been found that water works and water power engineers do not make as much use of it as they might. This I may say is not the fault of the work itself, for those who do keep in touch with it, those who are watching the investigations, accord them the highest approval.

It seems to me that this society might well take an official part in those investigations, and appoint some committee with an appropriate name with whom those in charge of these Federal investigations might consult to the end that the usefulness of the work may be brought to the highest degree of efficiency. It may be that the work which is being carried on is not of a sufficiently definite or purposeful character to be used by water works men generally. If such is the case we want it changed. If you as a society will take the matter up, and appoint a committee to consult with and advise us, there may grow out of these investigations the greatest good and the greatest amount of benefit to water works engineers.

DISCUSSION.

MR. MAURY: I think that that suggestion of Mr. Leighton's is worthy of our careful consideration. I do not know how many of us are familiar with the importance of the work that this department with which Mr. Leighton is connected is carrying on. I happen to have had the pleasure of listening to Mr. Leighton before in other places and to have heard his graphic descriptions of the work of his department, illustrated by lantern slides, and thus have been able to form some idea of the value of the work he is doing. In addition to that, as a good many of us know, the government is issuing all the time for our benefit a great many valuable bulletins on matters which are of special interest to water works men. It seems to

me in order that this work may be carried on so as to be of the greatest possible benefit to us, we ought to take, as Mr. Leighton kindly suggests, a sort of supervisory interest in it. I think his suggestion that a committee from this association be appointed to keep in touch with these matters is an excellent one, I move that such committee be appointed.

Mr. Sherrerd: I know something of the work carried on by this department and believe it is of vast importance to water works people. I remember one investigation in particular, on the Hoosick river near Troy, in which the purity of the water was discussed. Kindred subjects of investigation carried on throughout the entire country cannot fail to be of great benefit to water works men. I would, therefore, very gladly second Mr. Maury's motion.

Mr. F. A. W. Davis: There is a committee on stream pollution of this association. Is it not the duty of that committee? Congress should pass a general law regarding stream pollution, because streams often flow through different States. Whether the committee has dropped out of sight or expects to do anything, I am unable to say. I am very heartily in favor of Mr. Leighton's suggestion, and the association ought to fall in with it.

Secretary Diven: The committee on stream pollution, referred to by Mr. Davis, memoralized Congress to pass laws on the subject and presented their report to this association at Richmond, and asked to be discharged, as they had performed their duty. Mr. Monjeau was secretary of that committee, and did most of the work. Pursuant to their request the committee was discharged, having completed the work so far as they could. I would like to suggest that Mr. Leighton meet the members of the Executive Committee immediately after the adjournment of this session and consult with them on the appointment of this committee, and as to a proper name for the committee, etc.

Mr. Hazen: I support most cordially the suggestion for the appointment of a committee to co-operate with the Geological Survey.

The work of the Geological Survey has been extremely useful. In making the topographical maps of the country it has

performed one of the most useful works that the United States Government has ever undertaken.

The investigations as to the flow of streams and the qualities of the waters in the streams of the country have not been carried far enough to have a corresponding value up to the present time. But this work is being prosecuted; and when full records are available they should be of the very greatest value, especially in relation to water works problems.

If we can do anything to help Mr. Leighton's good work, I am most cordially in favor of doing it.

Mr. F. A. W. Davis: Our company has spent quite a sum of money and succeeded in getting an injunction against the American Strawboard Company. Notwithstanding what we have accomplished, we feel it is necessary to do a great deal more. We are now expecting that the city of Indianapolis will take steps towards keeping our supply from being polluted. It is now advertising for bids to construct a sewer to keep the surface water from running into our source of supply, and we are very deeply interested in the subject of stream pollution. We took the matter up with the United States government. It has built or is building Fort Harrison on Fall Creek. We said to the government that we would seek an injunction against it unless there was provided some means of taking care of the sewage. It accordingly entered into an agreement, not specifically in writing, but we have the assurance of the officers that they will put in a purification plant, that it will not allow sewage to go into the stream called Fall Creek. There is pollution for ten miles along our stream from the city, and yet the city has taken no steps whatever to prevent the pouring of sewage into the stream every day.

Dr. W. P. Mason: Although a firm believer in the decrease of virulence of the typhoid germ, by reason of lapse of time and distance of river flow, I must surely agree with the author of this paper that it is unsafe to depend upon such impaired virulence as the only safeguard against disease.

It is wise to add, however, that the water purveyor must solve the problems presented by his work with due appreciation of the special conditions involved. He must decide each case upon its own merits without slavishly following some

general dictum which may be too broad to apply to the instance in hand.

As a carollary it may be added that experimental results established in one locality may fail to fit conditions arising in another section of the country.

Although I feel that it might readily cause a hardship to "over protect" our great tidal rivers at points near the sea, I very thoroughly side with the author in his efforts to arrest the growing pollution of the legitimate sources of inland water supply.

The schedule of polluting substances as given by the author, is interesting, but would it not be hard to apply? Thus suppose Troy or Albany using Hudson River water, should introduce a sewage treatment consisting of septic tanks followed by sand filtration, would not the effluent be certain to contain more salts of the metals specified than the quantity thereof found in the raw river water? If so, the effluent would be excluded from river disposal, provided I correctly understand the author's proposition.

Mr. Dunham: One position taken by the author, viz., that we have to depend more upon policy than upon justice for any improvement, seems opposed to our natural or first impressions and it should only be accepted upon well-defined and abundant evidence.

There is a difference in the barrenness of results in reform movements between those cases where individuals act independently and where they are obliged to act collectively. Note the rapid progress in breaking up individual habits that once made street cars so unsanitary. When the fact that danger was imposed upon others was known, each individual, comparatively speaking, was ready to exercise care and did exercise it largely through his sense of justice. Arrests were very few and the reform was very complete. But when it is necessary for men to act collectively to secure a change or to make expenditures, the whole subject becomes complicated and enlightened action correspondingly difficult to secure. The sense of justice may not be less active but it is of necessity obscured by many considerations. Take the case of Pittsburg: No individual act of the average resident would add much to the purity of the

water supply. He could vote, it is true, and thus act in conjunction with others; but observe the difficulties before him.

"Are we sure of the best plan?" "Will the important work be carried out in the best manner? There are many methods of filtration." "Even experts do not always agree." "Is this the best time to act?" "Are the present officials proper men to be intrusted with such vast expenditures?"

The average voter is not an expert in filtration or finance. He may have good average ideas of justice and of policy, too, and yet fail to do his whole duty. He faces a question of living morals as well as of dead bodies. He is entitled to a little sympathy and may for that reason be a better factor in social progress.

One duty of a commission should be to see that small downstream villages or cities are not imposed upon and made to suffer for the social and economic development conferred upon large municipalities. If pollution is necessary and in turn makes filtration necessary or makes it more expensive for the smaller community, the commission should have authority to apportion and ascess the expense whatever it may be. In that way the economic development would be more uniform and principles of justice further illustrated.

Mr. George W. Rafter (by letter):

Mr. Leighton's paper is a consideration of some of the more patent phases of river pollution. The theory of river pollution, not only as to its causes and effects, but as to the economic questions involved, has been at one time or another pretty thoroughly considered, although it may be well enough to restate the facts about such as a lesson, but there is an unsatisfactory side to such writing in that we never get beyond a statement of the elementary principles, and everything treated in this manner is left in about the same state as before.

The author's schedule defining the character of the pollution substances which should be prescribed by statute, while differing in several particulars, reminds one of the statement of the English Rivers Pollution Commission of thirty years ago. As it is possible that some of the members of the American Water Works Association have not seen this, it is herewith given for comparison:

We recommend that, with certain exceptions in reference to standards (d) and (e), the following liquids be deemed polluting and inadmissible into any stream:

(a). Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size, for a period of at least six hours, or which, having been so subjected to subsidence, contains *in suspension* more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid, or which, not having been so subjected to subsidence, contains *in suspension* more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(b). Any liquid containing *in solution* more than two parts by weight of organic carbon, or 0.3 part by weight of organic nitrogen in 100,000 parts by weight.

(c). Any liquid which shall exhibit by daylight a distinct color when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(d). Any liquid which contains *in solution* in 100,000 parts by weight, more than two parts by weight of any metal, except calcium, magnesium, potassium and sodium.

(e). Any liquid which in 100,000 parts by weight contains, *whether in solution or suspension,* in chemical combination or otherwise, more than 0.05 part by weight of metallic arsenic.

(f). Any liquid which, after acidification with sulphuric acid, contains in 100,000 parts by weight more than one part by weight of free chlorine.

(g). Any liquid which contains in 100,000 parts by weight more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(h). Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(i). Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

(k). Any liquid exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing in suspension in 100,000 parts, more than 0.05 part of such oil.

In 1894, in Sewage Disposal in the United States, the writer laid down the following classification of streams, with reference to pollution, and he has yet to see this classification improved upon:

Streams may be divided into five classes, namely:

(1). Streams which are the sources of public water supplies,

and which are not polluted by either sewage or manufacturing wastes.

(2). Unpolluted streams which are not now the source of public water supplies, but which are likely to be so used in the future.

(3). Streams either polluted or unpolluted which are not the sources of public water supplies, and which are not likely to be so used in the future.

(4). Streams which are now the sources of public water supplies, and which are polluted with both sewage and manufacturing wastes.

(5). Streams which are now the sources of public water supplies, and which are polluted with manufacturing wastes only.

In regard to (1), it is clear that the thing to be done is to keep them in the same condition for all time to come. To this end, sharply cut legislative enactments ought in the majority of cases to prove sufficient. The New York State Act of 1885, with some modification in the way of increased powers for the executive sanitary authority, could be taken as a model on which to build.

For (2), it is equally clear that definite measures should be inaugurated for preserving them so far unpolluted that, when actually needed for water supplies, they may be so used without prejudice by reason of the previous occupation.

To this end each State needs some competent authority with a thorough knowledge of all the streams, ponds, lakes, etc., of the State. In Massachusetts, the State Board of Health is made the custodian of the inland waters, and given powers which enable it to properly decide each case on its merits. In New Jersey the legislature at one time had under consideration an act leading to State custody of inland waters, which, however, failed to pass.

For (3) it is probably permissible to use the streams as sewers and common drains, and the chief question to be considered is how much pollution any given stream will stand without becoming offensive to the senses or dangerous to health.*

By way of illustrating the third section of the foregoing classification, we will refer to conditions as existing in the Mohawk valley in the State of New York. The catchment area of Mohawk river is 3,468 square miles. The population of

*See Sewage Disposal in the United States, p. 73.

nineteen principal towns situated in this valley in 1900 was 216,000. The river receives the sewage of Rome, where the catchment area is only 184 square miles, and also of Utica, with catchment area of 524 square miles. The Mohawk river is not the source of a water supply and is not likely to be, but the Hudson river, of which it is a tributary, is the source of the water supply of several large towns, among which may be mentioned Albany and Poughkeepsie. The cities of Troy and Hudson have recently abandoned that portion of their water supplies which came from the Hudson river, taking in place thereof unpolluted upland streams, and Albany, Poughkeepsie and other towns on the river will ultimately follow this desirable example. New York city has also proposed to take a water supply from Hudson river at Poughkeepsie, but saner views have prevailed, and an unpolluted upland source has been selected.

New York State is perhaps fortunately situated in this particular, because it is possible for every city and town in the State to obtain an unpolluted upland source, without prohibitive expense and without recourse to the valleys of the principal streams. These streams, therefore, are the natural receptacles for the sewage, and there is no reason why they may not receive raw sewage so long as they do not become nuisances on account of it. It is true there is a sentimental view against this, but if we followed all the views of the sentimentalists, civilization would be at a standstill and we would return to the rude conditions of an earlier age.

THE ROLE OF PUBLIC WATER SUPPLIES IN THE SPREAD OF TYPHOID FEVER AS SHOWN CHIEFLY BY THE GREATEST TYPHOID EPIDEMICS.

By George A. Soper.

The fact that typhoid fever may be caused by impure water is no longer a question which it is profitable to discuss. It is nearly sixty years since it was first suggested that typhoid could be communicated in this way, and since then a vast amount of proof has accumulated to show that not only typhoid, but other intestinal diseases, may be transmitted through the agency of drinking water.

It is also a matter of general agreement that the amount of typhoid fever in the United States is much greater than is commonly supposed and that a large part, but by no means all, of it is due to public supplies of water which are inadequately protected against contamination.

In this paper we shall consider some of the ways in which water supplies become contaminated, and how extensive and fatal the results of this contamination may become, for there is much less unanimity of opinion among water works people, health officers and experts with regard to these matters than with respect to the mere question of the possibility that water may be a means of infection.

There are some facts connected with the spread of typhoid fever which science has abundantly proved and, in considering what follows, it will be profitable to keep these carefully in mind. It is necessary to recognize at the outset that typhoid fever is a specific, infectious disease which is caused, and caused only, when germ-infested matters which have been thrown off by persons sick with typhoid are taken into the stomachs of susceptible persons. In the strictest sense, it is the germs which are transmitted from person to person and not the disease.

The size of the dose necessary to produce a case of typhoid is not known. It depends, no doubt, upon the susceptibility of the person and the virulence and activity of the particular lot of germs which happen to be present. These differ greately under different circumstances.

Resistance to typhoid infection is not so much a question of general health as of natural or acquired immunity. The strongest persons often seem to be the most susceptible. By the continual use of a drinking water supply which is polluted with fecal matter, with its various kinds of intestinal bacteria, it is likely that some degree of immunity may be acquired. This is perhaps due to the fact that such water, not infrequently gives rise to mild attacks which act, like vaccination against smallpox, to prevent more serious illness.

Persons who seem to be immune are often, in reality, not so. There is a great deal of mild and unrecognized typhoid. It is entirely possible for an attack to be so light as not to interfere with one's business or pleasure.

Persons suffering from mild attacks of typhoid are the most dangerous from an epidemiological standpoint. A mild case has often given rise to a large number of severe ones. Persons who are experiencing very mild cases of typhoid go their ways without the least care being taken to destroy the infectious nature of their excretions. This fact is one of much importance, not only because of the possibility which it suggests of fatally polluting water supplies in ways which are not discoverable, but because it permits typhoid to be spread directly from person to person under circumstances which cause the disease often to be erroneously attributed to public water supplies.

The possibility that typhoid may spread from person to person through the contamination of food, and especially milk, should never be lost sight of in considering the part which public water supplies play in the spread of typhoid fever. Many outbreaks have undoubtedly been attributed to water supplies when the real cause has been contaminated food. The recent experience of Springfield, Mass., affords an interesting instance of this kind.

It is common to consider that far more typhoid is communicated by water supplies than in any other way, but it would not be surprising if future investigations should place water supplies in a less responsible position with respect to this matter. It is certain that some of the most sudden, intense and widespread outbreaks have been due to public water supplies and that large numbers of cases are annually produced by supplies which may be described as continuously, but usually moderately, contami-

nated, but so many other common means of communicating typhoid exist that it seems unreasonable to attribute most of our typhoid directly to public drinking water.

When typhoid fever is brought into the household, by a water supply or otherwise, it is likely to spread from the patient to other members of the family. The germs contaminate the food by contact with accidentally soiled and infected hands of nurses and other attendants upon the sick, by flies which have access both to the excretions of the patient and the food of the family, by dust containing germ-infested particles of excreta and by other means. These are exceedingly common methods of spreading typhoid and the number of such cases which occur in large epidemics is always great. Koch has called this most direct transmission of the germs of typhoid from one person to another contact infection; it has also been termed comrade infection; it is often erroneously designated secondary infection.

The excretions which are dangerous in typhoid fever are all of the normal and abnormal excretions of the body, except sweat. The bowels are generally regarded as the chief seat of bacterial multiplication, but it must not be forgotten that the germs of typhoid may migrate to any part of the anatomy and that the sputum and urine may be infested. In fact, peculiar dangers lie in the urine. These dangers arise largely from the fact that the urine of the sick is not generally suspected of being infested, and is seldom disinfected. Yet it may contain vast numbers of the bacilli and contain them for weeks and months after the patient appears to have thoroughly recovered. It is obvious that no typhoid patient should be discharged from medical care until his urine is proved by bacteriological analysis to be free from typhoid fever germs. Such restriction is, however, seldom practiced.

With such a wide distribution of the germs of typhoid which must constantly be taking place, it is evident that if great numbers did not perish quickly, every city, town and village would become as saturated with them as were our American military camps in the war with Spain, in which event they would be in a perpetual and universal condition of epidemic. Obviously it takes a very unusual series of incidents to produce an epidemic through the agency of a public water supply.

Practically and experimentally it is known that under con-

ditions which obtain nearly everywhere in nature typhoid germs succumb in great numbers. Direct sunlight kills them in a few minutes; other bacteria destroy them; and they perish by drying and by being deprived of those conditions of heat and food to which they are accustomed in the human body.

It is not known that typhoid germs ever find conditions outside of the body so favorable that they can survive more than a few weeks, although the history of nearly every great typhoid-water epidemic seems to point to the possibility that the germs may live much longer than the results of recent laboratory researches indicate.

If they had not the power of living a long while in water, it is not clear how such long continued epidemics as those of Plymouth, Butler, Ithaca and Watertown could have occurred. The total number of cases in these four epidemics was about 4,500 and their duration many months. An intimate experience with three of these epidemics leads to the opinion that while many cases were undoubtedly due to a strictly local transmission of the germs, some were ascribable to the water supply many weeks after the last date when the supply could have received its infectious material.

Again, from experimental evidence, it would appear that nothing need be feared from the few unusually resistant germs which escape destruction by sunlight, drying, freezing, and by submersion in water. Practically, however, the fate of the survivors appears to be a matter of pre-eminent importance. It is the survivors which produce our epidemics.

The power of typhoid germs to resist destruction by the unfavorable conditions which they meet in rivers and on river banks depends, of course, largely upon the severity of those conditions. The conditions vary just as the resistance of different lots of typhoid germs varies.

In some instances the powers of resistance of the germs seem to have been remarkably great. The bacilli which produced the Plymouth epidemic must have been frozen on the bank before a thaw released them and allowed them to flow into the third reservoir, and so to the distribution system of the public water supply. The epidemics of Ithaca and Watertown both occurred in the early spring after exceedingly cold winters, and at a time when heavy thaws probably allowed the frozen infectious mat-

ter to enter the rivers from which the water supplies were derived. According to theory, based solely on experiments, there should not have been enough germs left, after the long exposure to the low temperature of winter, to have produced either epidemic.

In considering the ways in which public water supplies may become so contaminated as to give rise to epidemics, it may not prove uninteresting to review the leading facts of some of the greatest epidemics of this kind of which we have any record.

There occurred at Caterham, England, in 1879, in a population of 5,800, a typhoid outbreak numbering 352 cases and 21 deaths. The cases were spread over a wide area. The means of infection was a public water supply controlled by a private company. The water was derived from wells about 490 feet deep, one of which was polluted by a mildly sick workman during construction. The outbreak lasted from January 19 to the end of February.

One of the most intensive outbreaks of typhoid fever which have ever occurred in the United States took place at Plymouth, Pa., in 1885. Out of a population of 8,000, there were 1,104 cases and 114 deaths. The epidemic lasted from April to September. The water supply, obtained from mountain streams, from a private company, became infested with typhoid germs from a house which was located upon the banks of a main feeder of one of the water works reservoirs.

An extensive epidemic of typhoid occurred in the lower Tees River Valley, England, in 1890-1. It was divided into two distinct periods of six weeks each. The first outbreak occurred on September 7, and lasted until October 18, 1890; the second began on December 28, 1890, and lasted until February 7, 1891. In a population of 251,976 there were in these two outbreaks a total of upwards of 1,330 cases and 100 deaths. It was found that the communities which were attacked by fever obtained their water supplies from the Tees River and that the banks of this stream were grossly polluted. Extensive floods, antecedent to the outbreaks of fever, washed the filth from the banks into the river and it is believed that the drinking of this water caused the epidmic.

A typhoid epidemic occurred in the Merrimac Valley, Mass., in 1890 under conditions which were somewhat similar to those

of the Valley of the Tees. Several large cities, notably Lowell and Lawrence, suffered severely at this time, but the exact number of deaths and cases, and the dates of their occurrence are not available. Basing a calculation on the Reports of the State Board of Health of Massachusetts, there were in Lowell, with a population of 77,696, by the U. S. Census of 1890, 858 cases and 65 deaths from April, 1889, to March, 1890, and 1,997 cases and 152 deaths from April, 1890, to March, 1891. At Lawrence, with a population of 44,654, in 1890, there were 693 cases and 53 deaths from April, 1889, to March, 1890, and 1,099 cases and 84 deaths from April, 1890, to March, 1891. The totals for Lowell and Lawrence for the two years named were 4,647 cases and 354 deaths. Investigations by the State Board of Health showed that the epidemic at Lowell was due to an infected surface water supply, and that the sickness at Lawrence was largely attributable to drinking water containing the sewage from Lowell.

Far more extensive than any of the water epidemics have been those among soldiers confined in military camps. In the United States camps, during the recent war with Spain, there were among 107,973 officers and men in 92 regiments, according to the estimate of the Official Board of Inquiry, 20,738 cases and 1,570 deaths from typhoid. These cases were distributed among several camps, but we may select one, the camp at Jacksonville, to illustrate the extent to which typhoid was prevalent in one locality.

There were located at Jacksonville 16 regiments of a mean strength of 18,749. Among these it was estimated that there were 3,417 cases and 260 deaths. The fever in the army was not attributed to the water supplies, so much as to the transmission of the disease by contact.

These war epidemics are peculiarly interesting, however, to water works people, for it is not improbable that the soldiers going home convalescent from typhoid to every part of the country carry the germs of disease which are presently to sweep over the whole continent, polluting many water supplies and giving rise to some of the greatest epidemics which have ever occurred.

In the Civil War in the two years, 1862-3, there were reported among 460,000 men in the Atlantic region, 29,666 cases and 7,092 deaths from typhoid fever.

In the South African War, among less than 230,000 men there were between 50,000 and 60,000 cases and 8,000 deaths from typhoid.

At Bloomfontein, from the second of March to the middle of May, 1900, there were 4,667 cases and 891 deaths from typhoid among about 40,000 troops.

In the Crimean War for a period of seven months, between October, 1854, and April, 1855, out of an average of 28,939 men, there perished in hospitals and on hospital ships, 10,053 men from sickness, a large part of which was undoubtedly typhoid fever.

In the spread of all of these war epidemics polluted water supplies undoubtedly played an important, though by no means the leading part.

In 1893 a much quoted epidemic of typhoid fever occurred at Worthing, England, and ran from May to November. Worthing, in 1891, had a population of 16,606. The number of cases recorded for this outbreak was 1,411 and the number of deaths 168. The epidemic was due to a water supply obtained from wells put down into strata which were later found to be badly polluted by leaking sewers and broken drains.

An extensive outbreak occurred at Grand Forks, North Dakota, in 1893-4. The population of Grand Forks at the time is estimated to have been about 6,000. There were 1,245 cases and 96 deaths reported. In this instance the cause of the epidemic was the public water supply obtained from the Red Lake River. Infectious matter is believed to have come from the town of Crookston, on the river, sixty miles above Grand Forks.

In 1897 a typhoid fever outbreak occurred at Maidstone, England, and ran from August to December. The population of Maidstone at that time was estimated at 33,830. The number of cases reported was 1,928. There were about 150 deaths. The channel of infection was a water supply furnished by a private company. The water was taken from springs, and the site of one of these during a period of dry weather had been used by a party of hop pickers for a camp. Typhoid fever existed in the camp, and it is believed that when the drought was broken, the water of the spring carried the germs of typhoid to the city.

An epidemic of typhoid fever broke out in New Haven,

Conn., in 1901. During the months of April, May and June 479 cases were diagnosed. There were in April, May and June 70 deaths. The population of New Haven in 1900 was 108,027. The water supply was largely obtained from surface sources. Several cases of typhoid fever were found to have occurred in a house on the banks of a stream contributing to the water supply and the infectious material which produced the epidemic was believed to have been washed into this stream after having been released from a frozen condition by a heavy rain and thaw.

At Ithaca, in 1903, there was 1,350 cases and 82 deaths from typhoid fever in a population of about 13,156. The water supply was the medium of infection. The water was obtained from a private company from creeks which were polluted by numerous houses upon their banks. About 500 homes were attacked by the disease. The epidemic began on the 11th of January and extended until the first of April.

At Butler, Pa., an outbreak of typhoid fever with 1,348 cases and 111 deaths occurred in 1903. The population at the time was about 18,000. The epidemic was caused by the water supply, which was derived from polluted Connoquenessing Creek. Under ordinary circumstances the water had been filtered, but for a period of two weeks between October 20 and 30, the filters were put out of service in order that certain alterations to the pumping machinery could be made.

Typhoid fever broke out early in January, 1904, at Watertown, N. Y., and was epidemic until the latter part of April. The total number of cases recorded was 614 and the deaths 44. The population of Watertown was 24,194. The source of the epidemic was the water supply owned by the city. The water was obtained from the Black River, which was polluted by a number of villages and cities, the nearest of which, Deferiets, a mill settlement with a sewerage system, was ten miles above the intake of the Watertown water works. The outbreak of the epidemic had been preceeded two weeks earlier by a thaw and freshet in the river.

All of these water-caused outbreaks of typhoid were characterized by the suddenness of their onset and the large proportion of the exposed population which was attacked. The water supply was, moreover, in every case, suspected and eventually proved guilty.

Typhoid fever from public water supplies may develop in either of two ways. First, it may occur as an active outbreak. Such epidemics usually come on with explosive suddenness, attack a large number of the population furnished with the water, spread to persons and localities beyond the reach of the water supply and pass off very slowly.

Typhoid epidemics develop, in the second place, in a way which may be described as only comparatively epidemic, that is, they occur more as long, low waves of disease than as explosions. Because of their insidious progress they produce none of the sensational features common to outbreaks of the first class. Examples of this kind of outbreak are very easy to find in America. Practically every city whose typhoid death rate is high may be suspected of belonging to it.

The causes of the two types of outbreak are generally as unlike as their results. As a rule, explosive epidemics, when due to water supplies, are caused by sudden and severe pollution, such as the release of relatively large accumulations of fecal matter.

The water supply which is most likely to produce a sudden epidemic is the one which is derived largely from brooks and creeks in a sparsely settled rural district. Sometimes a number of sources of defilement exist, a fact which is clearly evident on inspection. As a rule, the infected matter comes from one patient, or a few, whose stools and urine have been thrown upon the ground without disinfection in such a way that the infectious matter has accumulated and subsequently been washed into the water supply by rain.

Ample warning of a great epidemic is usually given in advance, in the form of slight epidemics of diarrheal diseases, which are more or less typhoidal in character. These slight epidemics should be regarded as danger signals. Water works officials and health authorities should be constantly on the watch for them, and, when discovered, their cause should be promptly looked for and removed. Great epidemics always get their rise in ways which produce the minor ones. Waterworks officials should, therefore, be alert to appreciate the significance which attaches to slight outbreaks of diarrheal disease. Are they? It is probably not too much to say that in scores of cities and towns in this country, danger signals of typhoid epidemics exist at the present moment.

Discussion.

Mr. Ellis: The water supply of Jacksonville, Florida, was not responsible for the epidemic of typhoid fever that prevailed in some of the camps; it was worse in the earlier camps where they were laid out by the old method. The officers' quarters being laid out on the highest ground, next the camp for the men, immediately back of the men were located the kitchen and mess tables, and a short distance in the rear of the kitchen the earth closets and pits into which refuse was thrown and covered, occasionally, with earth. All the camps were supplied with water by having a pipe run back of the camps so as to give a faucet for the use of each company. After the typhoid became epidemic the water was examined and found to be all right. The water is derived from deep artesian wells, pumped direct into the mains and to the faucet without any chance for contamination. After a long series of investigations it was finally decided that a few cases of typhoid had been brought into camp by some of the men; this infected the earth closets and pits and the flies in flying back and forth from the pits to the food prepared for the men to eat had carried the infection, so precautions were taken in the new camps to prevent this.

In one camp of six or eight thousand men where the sanitary arrangements were of the best there was no typhoid. The camps where the fever was worst were in the northern part of the city, yet there was no typhoid among the citizens. All of which I think establishes clearly and conclusively that typhoid fever can be distributed by other means than through the water supply.

Dr. W. P. Mason: Although the greater number of bacteriologists contend that the typhoid germ has a strictly typhoid ancestry, yet those who oppose this view have a very sizable following who hold that the bacillus typhosus is frequently derived from a modified saprophite. This latter belief is surely a good working formula for the sanitarian and enables him to exercise his activities upon the side of safety, while the specialists are seeking for further facts wherewith to support their several dogmas.

With the advance in the inspection and care of water sup-

plies it must of necessity follow that they will become less and less a causative factor of disease, and the typhoid of the future will, relatively, be more frequently traced to other sources.

The author wisely calls attention to the prevalence of mild and unrecognized cases of typhoid fever, and to the greater danger arising from them.

It might be added that such cases are dangerous to the patient as well as to the neighbors, by reason of the lack of care given them and the consequent exposure to relapse.

As to the likelihood of the disease spreading throughout a household by "counter infection," that will largely depend upon the class of people among whom the fever primarily appears. With filthy people the danger is material, but among those of cleanly habits, who are alive to the necessity of following sanitary instruction, there is no reason to fear an extension of the disease.

The author has given interesting data concerning sundry of the typhoid epidemics of the past, and the death rates are particularly worthy of attention. It may not be without interest to add that in the case of the Maidstone outbreak the contributing cause was the presence of large and deep "sun cracks" in the stiff clay soil, which permits surface pollution to reach the ground water without the intervention of suitable soil filtration.

Mr. Dunham: In this paper the interesting statements and figures relating to epidemics are apparently in error in one particular. As it is an error in which there can be no balancing or partial correction in the natural order of things, there is the greater reason for referring to it. While unimportant in certain small towns or cities it becomes of greater importance in large cities or in general statements concerning large numbers of people.

When an epidemic occurs and runs its course, the results or final figures are the recorded number of cases and the number of deaths in the interval. These, covering a period of weeks or months, are accounted the work of the epidemic and find a place in the literature pertaining to that disease or that locality.

In any such case or instance let us suppose there has been

no epidemic. We could not assume that no deaths from the disease, say typhoid fever, would have been recorded in the city during the long interval. The records for many past years, when no epidemic occurred, would refute such an assumption. And it is evident that a fair average of cases or of deaths in normal periods should be deducted from the records of the epidemic period if it is desired to learn how severe the epidemic was, or to state in figures the actual loss of life or number of cases. Absolute accuracy could not in this way be reached, but an approximation much nearer the truth than are the recorded figures, is easily possible.

In a town of few inhabitants, like Plymouth, the correction could be disregarded; but in a city as large as Butler, Pa., it would begin to show, and in New Haven, Conn., for instance, or in the 230,000 troops, it becomes essential to ask what the normal typhoid death rate is in one case, and in the other how many enlisted men would have died of typhoid fever had they remained in their own homes.

The author of the paper is familiar with fever statistics from every part of the world and corrections made by him of these widely circulated figures would be of especial interest and value. So also would any omitted facts or reasons going to show that the corrections ought not to be made.

In applying corrections to figures obtained from assembled troops, it might be noted that habits are often favorable to the disease and that the age of the soldier corresponds with the age of susceptibility to the disease and the death rate among enlisted men if at home may be in excess of the rate for all ages.

Until people generally are well, or about equally well, informed the contact or comrade infection will tend to obscure the real or first cause of an outbreak; in some instances making the attack seem to be more, and in other instances less, severe than it really is.

Infection along a milk route in certain parts of a city might cause but few cases while like infection in other districts in the same city would apparently be the cause of many cases.

Mr. Martin Prenter: Mr. President—I have listened with much interest to the able papers that have just been pre-

sented on Sewage Disposal, River Pollution, Typhoid Fever Epidemics, and Filtration of Water. They have all been full of ripe thought and wholesome truth for men like ourselves, who have to deal with the problem of an improved public water supply. It is well for each one of us to learn all that is to be known on these subjects, and with this knowledge address ourselves to the working out of our own salvation so far as the source of the water supply for our own territory may require it.

One speaker referred to the large number of typhoid fever cases in the city of Pittsburgh, and the great mortality in that city from this disease during the past few years. This I know to be true, for in the line of my duty as secretary and general manager of the Monongahela Water Company, a private corporation, which supplies nearly one hundred thousand of the population of that city, I have kept a close watch for many years on the typhoid fever statistics of the Bureau of Health of that city.

The portion of Pittsburgh lying south of the Monongahela River and known as the "South Side," gets its public water supply from the Monongahela River through the agency of the Monongahela Water Company, while the rest of the city is supplied from the Allegheny River through the agency of the city water works. As required by law, physicians report all cases of contagious disease, including typhoid fever, to the Bureau of Health. These reports show that a great majority of all the typhoid cases reported come from the territory supplied with water from the Allegheny River, while the South Side some months has only *five or six per cent.* of the total number of cases reported, although it has fully one-fourth of the entire population of the city.

River pollution from sewage, etc., above the intakes of the pumping stations on both rivers is very bad and perhaps worse on the Monongahela River, for the towns of McKeesport, Braddock, Homestead and other smaller places, are located along its banks less than fifteen miles above our pumping station.

Now, the fact which I wish to call to the attention of the members of this association, and more particularly the filtra-

tion experts, is the small number of typhoid fever cases among the community using water from the Monongahela River. This is due, I believe, to the influence of the water from the Youghiogheny River, which flows into the Monongahela River at McKeesport, and mixes with it for about fifteen miles above the intake of the Monongahela Water Company's pumping station. This water from the Youghiogheny River is largely impregnated with the sulphur water from the coal mines along its banks, and has been said by Prof. Phillips, Professor of Chemistry in the Western University of Pennsylvania, to be the salvation of the Monongahela River as a source of public water supply without adequate filtration. In this connection it should be borne in mind that up to this time none of the public water supply distributed in Pittsburgh is filtered, but we expect that in the course of another year or two the sand filtration plant now being constructed by the city will be completed, and a clean water, as well as a pure water, will be delivered to all the citizens of Greater Pittsburgh. In addition, I might say that the mine water of the Youghiogheny is neither an unmixed blessing nor an unmixed evil, for while it helps to eliminate the evil effects of sewage pollution in the Monongahela River, it renders its water, particularly in time of low river, very objectionable for steam boilers, on account of corrosion of boiler sheets and rivets.

My chief reason in calling attention to the conditions found in Pittsburgh so far as the two sources of its present public water supply are concerned, and the typhoid fever cases as referred to, is the hope that filtration experts of this association may study these conditions for themselves and make profitable use thereof along lines of purification of water polluted with public sewage.

Dr. Soper: A great deal of attention has been given to the situation at Pittsburgh, but it seems that all of the information available has not yet been published. To some of us, I think, the last speaker has brought a surprise. For one I sincerely hope that when his remarks are sent to him for approval and revision that he will incorporate into them such analytical data as he has collected and such impartial official evidence with regard to this subject as he may possess. I believe that such

information will be of great value not only to the reputation of his company, but to students of epidemics and water works people in general. I would almost say that he owes it to the world to give these facts out in a most precise way. The fuller the information, the more we will all value it.

Mr. Prenter: I am not a scientific man, not an engineer, and not a chemist, but simply one who has had some practical experience in dealing with the typhoid statistics of Pittsburgh in connection with its public water supply. These typhoid statistics tell their own story, and they bear out the statement that this mine water from the Youghiogheny River has been the salvation of the water of the Monongahela River for domestic use in Pittsburg under existing conditions for many years.

Mr. Sherrard: I understand that Mr. Leighton in speaking about sewage disposal stated his conclusion to be that where a stream was used for water supply and tests of the water showed that it was polluted, that the effluent from any sewage disposal works before passing into such stream need not be treated to as high a degree of purity as to entirely remove the pathogenic germs. He seemed to hold that a certain amount of pollution might be permitted as long as it was odorless or not putrescent. It seems to me that we cannot subscribe to such a conclusion, particularly where it might be possible on the drainage area to prevent the pollution of the stream at least from human excrement. In such cases particularly, the effluent from the sewage disposal works would be dangerous because it would be concentrated and would be apt to contain a large amount of pathogenic pollution which could be prevented on the watershed. If by due diligence such pollution could be prevented from entering the stream it would be a dangerous proceeding for us as water engineers to say that such an effluent would be harmless simply because it went into the stream without evidencing a strong odor. I think we ought to put ourselves on record as maintaining that the effluent from sewage disposal works entering any stream that is taken for a water supply ought to be purified to the extent that it would not carry pathogenic germs. Every effort should be made to avoid contamination from human excrement, because the

typhoid germs might be of sufficient vitality to withstand such treatment as would destroy other germs.

MR. C. A. BROWN: In relation to what the last speaker has said, we had a little experience of that kind in the work done at Oberlin, Ohio, several years ago, where a very efficient sewage disposal plant was established for a town of that size. We found that the effluent from the tile drains of the filtration system there carried on an average about 3,000,000 bacteria per c. c. In a distance of flow of something less than two miles—I do not remember the exact distance, but it was less than two miles—the count had decreased to something like 1,800, while the screen at Black River above where Plum Creek entered, showed about 2,100 bacteria per c. c. At the same time sewage effluent or flow in Black River was not altogether what we desired, although the stream was clear and satisfactory as far as I went.

Now, in relation to the statement made as to water taken from the Monongahela, I did considerable work along that stream several years ago. Conditions there vary largely.

I think Professor Monfort has figures on the work at Marietta that might be interesting in this connection, if he cares to give them.

MR. MONFORT: I want to mention a few facts in connection with the water derived from the upper Ohio. It has been with me for some time a matter of research to follow up the changes in the Ohio River in the territory below Pittsburgh. A filter plant has been operated at Marietta, while at a point twelve miles below, at Parkersburg, they have no purification system at all. During the Pittsburgh epidemic, at the Marietta plant they had coli in one sample because their supply of coagulant had run out. During the whole time there was but one case of typhoid in the city; when this was traced to its source it was found that the patient had been using water taken direct from the channel, while employed on one of the small boats. During the same period, at Parkersburg, twelve miles away, they had twenty-three cases. The cities are of about 20,000 population each. In one case freedom from typhoid was apparently traceable to non-use of raw river water. In the other city the cases were traceable to the use of river

water, showing that typhoid germs had been carried possibly along the entire range of some 250 miles from the Pittsburgh district, or from intermediate points where serious trouble had occurred. This goes to show that the stream in this case was the source of pollution and that the removal of pathogenic germs by filtration was adequate, making the water satisfy the requirements of a perfectly safe water.

MR. DUNHAM: It happens to be known to the speaker that when the present sewage plant at Oberlin was designed, a prominent sanitary engineer said there could be no possible harm follow from broad irrigation, although Elyria was taking its water supply at the time from Black River, of which Plum Creek is a tributary, at the distance of eight miles away, with a grade of fifteen to twenty feet to the mile. That was many years ago. It would be interesting to ascertain at the present time whether sanitary engineers would be in substantial agreement with the designing engineer.

MR. LORD: I represent a water works on the Adirondack watershed at Ogdensburg, N. Y., where we have a great many paper mills which dump the effluent from their digesters into the river from which we pump our supply. The acid they use to disintegrate wood pulp is sulphuric or sulphurous acid. Our commissioners have been very much interested in seeing to it that those paper manufacturers did something else with their waste liquid besides dumping it into the river. We have gone so far as to go to the legislature and ask to have a law passed prohibiting it. We have been active in having this waste liquor diverted from our stream, and I am surprised to learn that, apparently, we have been working against our own interests and that we should rather have invited these manufacturers to dump their sulphuric acid into our stream as the lesser of two evils; that it is better to have our insides eaten out with acid rather than to have typhoid fever! Mr. Hazen is somewhat familiar with the situation in our part of the country. Several miles below one of these plants we find that the river is so impregnated with this acid that water wheels will last but two or three years working in the river. I would like to have the backing of the members of this association, and if such is their understanding of the matter to go back to my

people and say that these manufacturers are philanthropists and are our friends, and we must hold out to them the olive branch!

MR. LEIGHTON: The stand which I take with reference to the purification of sewage has nothing whatever to do with sulphite pulp waste. We were considering sewage and typhoid bacteria. It is very well known that sulphite waste is one of the worst things that can be discharged into streams and one of the things that should not be tolerated. It is not contended that sewage or industrial waste shall be indiscriminately discharged into a stream, for infixing a standard of purity of sewage effluent it is hardly justifiable to insist upon a sterile effluent when it is to be discharged into a foul stream, or a stream in which the bacillus coli communis can generally be found.

In response to my friend Mr. Sherrerd, I say that there are cases where it will be far better to secure an effluent of the highest possible purity; but where you have cities located along the banks of the stream the water is going to be impure in spite of all you can do. The finest set of sewage works that ever could be made would not have prevented the great Lowell and Lawrence epidemics. That was an incidental pollution. No system of municipal sewage works could have prevented the Plymouth epidemic, or that at Ithaca, or that at Butler. The point is that upon inhabited drainage areas, especially those that have cities along the banks of the water courses there is natural under-drainage of the occupied land that must be impure, and this alone is sufficient to destroy the value of the raw water for domestic purposes. We must accept such pollutions, we cannot avoid them by any system of sewage purification that man can devise.

Now, granting that such a stream must be impure (and I am speaking of streams in general and not those of an upland protected water supply) I contend that it is folly to insist upon actual purity of sewage effluents when they are to be poured into a stream that is infested with typhoid germs, or at least in which the bacillus coli communis can generally be demonstrated. I submit that that is a fair and reasonable proposition; but please do not understand that I mean that industrial waste

and sewage should be poured into streams indiscriminately.

MR. HAGUE: I arise as a peacemaker. Mr. Leighton is mistaken in the situation, as Mr. Lord, of Ogdensburg, is gunning after the mine water in the Youghiogheny River which killed the microbes in the Monongahela River, and he did not refer at all to river pollution as set forth by Mr. Leighton.

MR. PRENTER: I do not approve of the pollution of a river in any way, shape or form, and simply called the attention of this association to what may be regarded as a remarkable fact, and which fact can be borne out by the statistics of the Bureau of Health of the city of Pittsburgh to-day and for the last ten years so far as the location of its typhoid fever cases are concerned.

MR. F. A. W. DAVIS: We have spent over $8,000 taking two thousand pages of testimony, and I feel that we have evidence of some value. I do not agree with Mr. Leighton. I think that sewage pollution should not be put into the streams without purification. So far as pulp refuse is concerned, there is nothing more injurious than strawboard pollution. It rots in the stream, poisons them and often blackens the water, and it will take the hair off an animal's feet. I know sulphuric acid does come into streams from mines. How to prevent that I do not know, but I am certain it is not beneficial to water or to humanity.

MR. LEIGHTON: One word more, with reference to mine drainage. I think everyone will agree that it is poor policy to turn mine drainage, or strawboard waste, or anything of that kind, into a stream; but the gentleman from Pittsburgh is perfectly correct in stating that there are peculiar conditions under which mine drainage is beneficial. I am very familiar with another case, having had it under investigation for more than a year, in West Virginia. We have there a case of mine drainage coming down one of the rivers into the north branch of the Potomac. There is above there on the North Branch a soda pulp mill that turns annually about 15,000,000 pounds of lime into the river. Those two substances mix and there is turmoil; but after flowing about thirty miles the water becomes clear by reason of the sedimentation produced by the mixture of those two substances. There is free sulphuric acid, there is

ferrous sulphate and there is lime—a pretty good coagulant. But at the same time that must be considered as a fortunate coincidence, and it is by no means any evidence that those two kinds of waste may, with justification, be turned indiscriminately into our rivers, although it acts beautifully there on the Potomac. The city of Cumberland is using the Potomac River water with a fair degree of satisfaction, but this water would be very foul were it not for these two pollutions which overcome all the difficulty.

I do not think we can pick out a case here and there to justify any kind of stream pollution. It works well on the Monongahela, however. The Federal Government has just finished an investigation of that. There is no doubt at all that those cities that are taking water from Monongahela River are better off by reason of that mine drainage than they would be without it; but that does not in any degree justify the pouring of the mine drainage into streams. If the sewage were removed from that river they would not need the mine drainage as an antidote.

Mr. Baker: One word before the discussion closes. I hope it will be impressed upon the minds of all the water works men here who have not followed closely the progress of sewage treatment that there is no practical method of sewage treatment that can be relied upon to produce an effluent which can be discharged with impunity into drinking water. We must either exclude sewage from the streams, or we must purify the water, or purify both the sewage and the water.

Mr. Geo. W. Rafter (by letter):

Mr. Soper begins this paper by remarking that the fact that typhoid fever may be caused by impure water is no longer a question which it is profitable to discuss. The writer agrees with this, but calls attention to his discussion of Mr. Baker's paper, on a preceding page, as showing some of the limitations which may be properly made.

The object of the author is to review the various cases where water-borne typhoid has been the cause of great typhoid epidemics and the writer will mention two cases, smaller than those cited by Mr. Soper, first, however, remarking that while contaminated milk has been the cause of a few minor typhoid

epidemics, the ordinary way milk becomes infected is by the use of infected water for washing cans. This point is important because the popular impression is that cows have typhoid fever, communicating it to their milk.

As the first case, the writer will cite the classical one at Lausen, Switzerland, which occurred in the summer of 1872, at which time Lausen was a village of 780 inhabitants, living in ninety houses. The last previous epidemic of typhoid fever was in 1814, when the village was occupied by soldiers. Not a single case had occurred since 1865, when a few were imported from Basle. The village is situated on gravelly soil, ranging from 35 to 60 feet above the Ergholz brook, the elevation of which is about the elevation of ground water beneath the village. Between August 7, 1872 and October 30 of that year, there were one hundred and thirty cases of typhoid fever, eight of which were fatal. On investigation it was found that every one of the one hundred and thirty cases had used water from a certain public well—not one had occurred among those who drank other water, only.

Investigation showed that on another brook which led into the Ergholz brook entirely below the village of Lausen, a man had become ill of typhoid fever on June 10, 1872, recovering in September. A second case ocurred July 10, recovering in October, and in August there were two others, mild and of short duration. The dejecta from these patients were thrown into the Furlen brook and it was afterwards discovered that there was a connection between the Furlen brook, below the point where contaminated and the public well. On placing a quantity of salt in Furlen brook, its presence in the public well was shown by a large increase, as determined by chemical examination.

This case was investigated by Dr. Hagler, who concluded that there was a communication between the Furlen brook and the public well, allowing water to pass through nearly a mile of intervening gravel and that the dejecta of the cases of typhoid in Furlen brook contaminated the water of that stream and that this water passed through the gravel without materially decreasing the activity of the typhoid germs.

Another case was that of an epidemic of typhoid fever at

the village of Springwater, New York, occurring in October and November, 1889, and studied by the late Dr. M. L. Mallory and the writer. This case was referred to by the late Dr. Albert R. Leeds, chemist of the Stephens Institute, as one of the most completely studied that he had seen.* This fact, alone, would make it worthy of mention in an enumeration of important cases, the more especially since the typhoid bacillus was definitely identified by Dr. H. C. Ernst of Harvard Medical School.

Springwater is a village of six hundred inhabitants, situated in a deep valley two and one-half miles south of Hemlock lake, the source of the domestic water supply of Rochester. There is a creek flowing through the village and into the head of Hemlock lake. It is a living stream, although in dry weather there is no flow on the surface by reason of the water sinking into the porous gravel forming its bed and flowing underneath the surface. The soil on which the village stands is open porous for a depth of 10 to 20 feet, below which are found thin ayers of impervious hardpan, alternating with beds of quicksand of variable thickness. The village is about 60 feet above the lake surface.

On account of the intimate relation of the village of Springwater to the water supply of Rochester, the Executive Board of that city directed Dr. Mallory and the writer to make such studies as might be of use to the water works authorities of Rochester in the future protection of the Hemlock lake catchment, and accordingly first attention was directed to a solution of the question of the origin of typhoid in Springwater village, where over twenty cases occurred. Space will not be taken to detail all the steps of the investigation—it is sufficient to say that the conclusion was that the disease originated with a walking case of typhoid. Chlorine in the wells of the region was determined, with the result of finding in one case, sixty-one times the normal; in another case, thirty-nine times; in another case, twenty-six times; and in another, twelve times.

Samples of water were also forwarded to Dr. Ernst for bacteriological and chemical examination. The chemical examinations were made by Dr. Charles Harrington of Harvard Medical School who, from the chemical point of view purely,

reported he could see nothing to condemn in the samples, but the results of Dr. Ernst's bacteriological examinations were quite different. In his report, he stated that from the face of the results alone it would be proper to condemn several of the waters, because they all contained a greater number of bacteria per cubic centimeter than is in accordance with good standard. In the water of one of the wells, he definitely identified the Koch-Eberth bacillus of typhoid fever.

Fortunately, all of the twenty-one or twenty-two cases were light and all recovered. This definite identification of the bacillus of typhoid in the well water from Springwater was of more than local interest, especially when made by a bacteriologist of Dr. Ernst's reputation, because in 1889 the identification had not been made very often—only fifteen well attested cases of identification, five of which had been made in this country and two of them by Dr. Ernst, being the record. The report of Dr. Mallory and the writer concludes as follows:

We regret that we are unable to give the detail of each of of the cases of typhoid fever occurring at Springwater last fall. We are unable to do this not only from a lack of disposition on the part of the attending physicians to prepare full records of their cases, but because of a lack of appreciation of the importance of such records on the part of the health authorities there.

The foregoing cases do not exhaust the list of important epidemics of water-borne typhoid fever which could be cited in addition to those given by Mr. Soper, but with those given in the paper they are perhaps enough to establish the proposition that water epidemics are common, although as stated by the writer on another page, there are a number of causes for typhoid fever and the writer has sometimes wondered whether after all a walking case was an adequate explanation of the origin at Springwater—whether, in short, there may not be another explanation which as yet is almost entirely untouched. He also considers that the other agencies frequently come in to increase the virulence of an epidemic.

A number of years ago, an item went the round of the papers stating that on excavating a considerable area just outside the walls of Rome, where many thousand typhoid victims had been buried during an outbreak of that disease at Rome

which occurred about the year 300 A. D., the workmen were affected with a serious endemic of typhoid. This item originally appeared in *Engineering News*, and the writer has been trying ever since to verify it, without success. If true, it would offer an explanation of many cases of which the evidence is based rather on the beliefs of the investigators than on any well ascertained facts learned by them.

The writer has had occasion to examine the evidence in most of the cases cited by the author, as well as a number of others not mentioned by him, and while the circumstantial evidence is strong that the conclusions arrived at by the investigator were right, nevertheless some of them lack direct proof that the conclusion is other than the investigator's personal belief. It is recollected that in one case the statement is made that since the water supply fulfils the conditions required to explain the facts, the investigator concludes that it is the source of the excessive amount of typhoid fever existing. The writer believes that in this particular case the conclusion is justified, but he merely wishes to accentuate the proposition that such evidence is purely circumstantial and would not convict in a court of justice. He considers, therefore, that while it is true that it is no longer profitable to discuss the fact that typhoid fever may be caused by impure water, nevertheless, in a broader sense, the causation is still unsettled and may be profitably discussed for a good many years to come.

Co-operation Between Municipal Water Boards and Health Boards.

Ellen H. Richards, (by letter).

Too often there seems to be antagonism, open or covert, between the water department of a city, and especially a small town, and the officials in charge of sanitary regulations.

The quantity of water used per capita has steadily increased from the score or two gallons of the earlier days of public supplies, until most cities provide one or two hundred, and from a section of Denver it is reported that one thousand gallons a day are required to keep the lawns in condition.

The beauty of city suburbs and village streets is largely dependent upon an abundant water supply. The increase of property value may offset the extra municipal expense. An increased tax rate is, however, not paid without grumbling.

When in addition to increased quantity a better quality is demanded by sanitary officials the water works board is between the upper and the nether millstone.

From a sanitary point of view, beside the expense of obtaining an excellent quality of water to begin with, much money ought to be spent on inspection of the water shed, on cleaning up nuisances and on helping the farmer to dispose of his refuse and drainage in such a way as not to contaminate the feeders of the town supply. The Metropolitan Water and Sewerage Board of Boston has set a good example in constructing and operating small filter beds and in supervising the construction of others in situations which, without this precaution, would soon become a menace to the quality of the stored water!

(W. W. Locke, Jour. of the Eng. Societies, Vol. 36, p. 139.)

A constant expense for patrol was not taken into account when many of the water works were constructed. Summer camps, picnic grounds, creameries, and intensively cultivated market gardens have all added to the difficulties of clean water supply.

To the city fathers what has been may well continue to be, and much grumbling is heard if the cost of delivering water is greater than the return from taxation.

Since public opinion must be at the back of municipal expenditure it is the duty of sanitary experts to see that this public opinion is enlightened. On the other hand, if the commercial side of this public utility is held before the people in such a way as to disguise the hygienic value of a given question, the sordid appeal will probably win.

The mass of the people are still skeptical enough of the hygienic value of a pure water supply, so that division in the camp of municipal affairs will be taken advantage of to avoid paying water taxes.

The money value of human life is not appreciated even by those whose physical strength is their capital, and they take chances in this as in other matters. Dr. Soper's paper shows clearly this side of the question.

Another item of expense which, if it had been incurred in most of the cases mentioned by Dr. Soper, would have prevented the epidemic, is that of laboratory control. In smaller communities where the expense of an outfit is not warranted, combination should be made, as has been done in the case of school supervision, and periodical examination secured.

No expenditure brings better returns than expert supervision. *But it must be expert and not amateur.*

There is perhaps no place in the government of small municipalities where there is need of healthier co-operation than in the education of the people to avoid heavy taxes by reasonable care in the use of land and waste of water. This waste of water lays a needlessly heavy burden upon the people and hastens the day, a day of trouble, in which a double supply will be absolutely necessary.

If, as Mr. Leighton claims, rivers are to furnish the cities and the cities continue to spring up and grow, the purification sufficient for manufacturing purposes will be all that can be expected. For drinking water a supply must be sought elsewhere. He has indicated the source in the ground water supply which would be amply sufficient and usually safe for domestic use. What a waste, to make 150 to 350 gallons of water fit to drink, when less than five gallons is used for drinking and cooking.

The double set of pipes might not be so costly as extensive filter plants with the expert laboratory control involved. The

danger of a double supply is in the ignorance and carelessness of the public. Until all the municipal, social and educational forces pull together to produce an enlightenment so thorough as to permit of an unconscious habit of right action, water boards will not dare to advocate and health boards will not dare to permit the use of double supplies.

It is then incumbent upon both to proceed with the education of the public as to the value of water, the danger of shortage (far more imminent than that of coal) to the ways and means of protecting present sources, to a respect for the scientific results secured at such a cost of life as Dr. Soper's paper has shown.

If both sets of officials would unite their efforts, would use the local press and all eductaional forces to this end, the life of the water works man would be a happier if a no less strenuous one.

EXTENSION AND IMPROVEMENTS IN THE SUPPLY MAIN, YARMOUTH, N. S.

By Geo. H. Robertson.

That a better understanding may be obtained, I will give you a short description of the gate house, intake pipes and supply main to pumping station.

The gate house is 17 by 12 feet, divided in the centre with a

Lake George.

12 inch brick wall, making two inlet chambers provided with valves and screens.

Three 12 inch pipes enter these chambers from the lake.

When the lake is at its highest level there are 7 feet of water over the inlet pipes. Average fall of lake 12 inches.

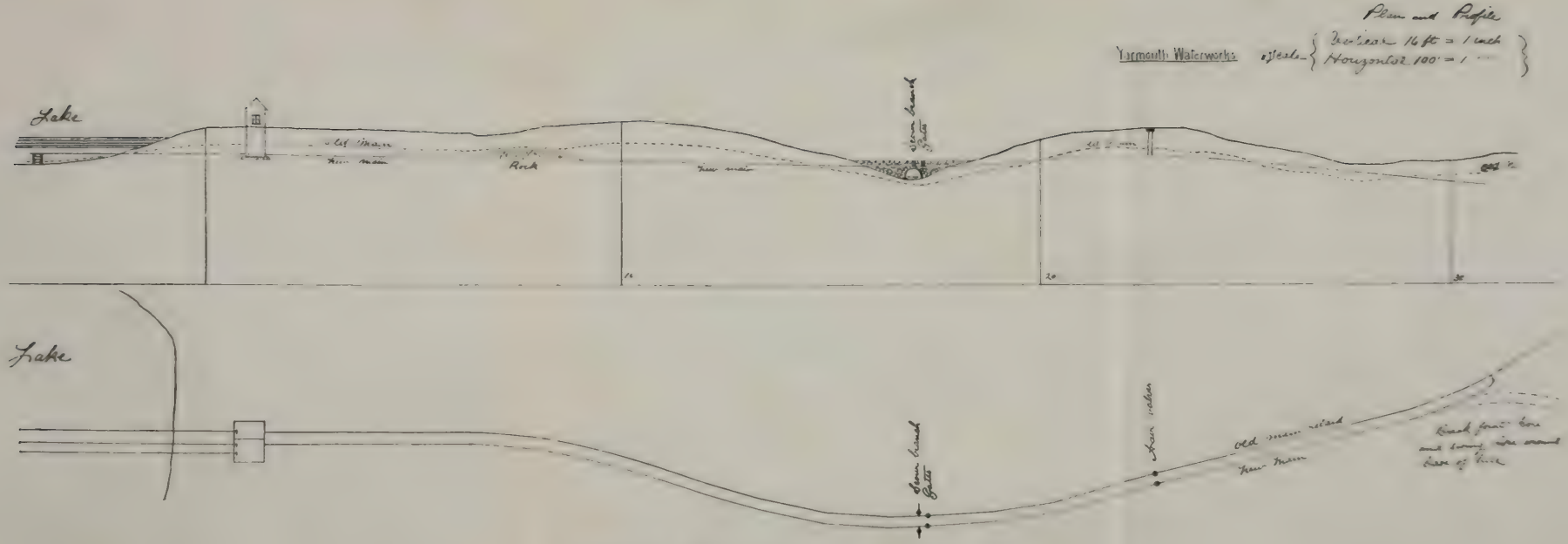
In 1891 the old supply main for a distance of 2,000 feet from the gate house was taken out, trench deepened and replaced with two new 12 inch mains laid on a true hydraulic grade, and connected to the old main.

Another View of Lake George.

caused the pumps to pound and rattle.

In September this year work was commenced at the point where duplicate main laid in 1891 connected with the old main.

Before connecting the new pipe we found that both the pipes laid in 1891 were heavily coated with tubercles. Not having any device for cleaning pipes, I dressed a piece of wood hexagon in shape, three feet in length with a disk of wood one inch smaller than the pipe, bolted on the end. On the front or cutting end, I fitted short steel scrapers placed diagonally with



PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906.

EXTENSION AND IMPROVEMENTS ON WATER MAIN, YARMOUTH, N. S.

This work was very expensive, owing to the soapy clay or quicksand formation, depth of cutting and heavy crib work. Average depth of trench 10 feet.

For the last fifteen years the single 12 inch supply main to town has been gradually filling with tubercular formations. These incrustations have so reduced the head or supply that after three hours running of the pumps the guage drops from 50 lbs. pressure to three inches vacuum. The consequence was that we pumped a mixture of air and water, which also

Another View of Lake George.

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the pipe, filling between the scrapers and disk with stiff steel brushes.

The scrapers cut the tubercles and the brushes cleaned the pipe. In the centre of the stick a one-inch hole was bored; through this hole a piece of strong rope was passed with thimbles spliced in each end. It was not possible with the low head to force the scraper through the pipes by water pressure.

Old and New Main Pipes, Depth 8 Feet.

To overcome this difficulty we floated a small line through the pipe with a block of wood attached, then drew a heavy line made fast to scraper. By frequent ramming with the water and eight men hauling on the rope, we managed to get it through.

Before making the second cut we spread the cutters and brushes and succeeded in giving the pipe a thorough cleaning.

A Corner of Lake George.

Hotel Lake George.

You will understand that this contrivance was built cheaply, with room for improvement.

Cost of scraper, $5.00. Rope, $20.00.

Time cleaning 2,000 feet, 4 hours.

From the end of pipe now laid and cleaned, we extended the new main another 1,000 feet, connecting with the old main, as shown in photograph. We could not disturb the old main until after the new pipe was connected, on account of depriving the town of water. We cut, made connection and turned on the water three hours from the time of shutting off.

Pipe Connection, Lake George, Yarmouth, N. S.

After the water was turned on the new pipe we disconnected the old main, removed, cleaned and relaid. The old main was laid without any regard to grade and was very irregular.

In many places the pipe was laid over hills, that could have easily been avoided. This line of pipe is nine miles in length, has been in constant service for 22 years, and was so badly

Gate House.

Laying Duplicate Main Pipe, Lake George. Yarmouth, N. S.

coated with tubercles that I concluded it would be easier and cost less to take out, correct the grade line and clean by hand.

For this purpose I made a scraper of different design from the one used with the rope. We disconnected and lifted 900 feet out of the trench in ten hours with six men, four on the derrick and two in the trench.

Method adopted to break joints was, first lift the end of the pipe with the derrick, then block under the bell end. By lifting and dropping suddenly the lead worked out without any trouble.

This make of pipe is turned and bored, has no groove or recess for holding the lead. No gaskets required, quickly laid and when properly calked will stand a pressure of 200 lbs.

Every length of pipe is rammed tight and solid. For ramming we use a piece of timber 20 feet long by 6 inches square.

We cleaned and relaid the 900 feet of pipe in two days with ten men.

As a result of this short extension and cleaning, the pumps get a better supply of water, run smoothly with no vacuum. Will probably make another extension next year.

WATER SOFTENING FOR MUNICIPAL SUPPLIES.

By George W. Fuller.

Limestone, shale and other rocks from which water dissolves salts of lime and magnesia are comparatively so rare in New England that local waterworks officials have but little occasion to consider the softening of water supplies. In the middle West and where limestone rocks abound, however, the waters frequently contain ten times as much mineral matter as those along the Atlantic Coast. Much of this excess of mineral salts is due to compounds of lime and magnesia which produce what is called "hard water."

Hard waters are less satisfactory than soft waters for practically all purposes. From a sanitary standpoint, however, there is no well defined evidence that within ordinary limits the hardness of water has much if any effect upon the health of water consumers.

In the household hard waters are seriously objected to on account of the large quantities of soap required when used for cleansing purposes. They also have an annoying effect on the skin when used for toilet purposes. In many textile industries hard waters give less efficient results than soft waters, and are more expensive on account of the additional quantity of soap and other products required. For steam raising purposes hard waters, as is well known, give much trouble through the deposits formed by the salts of lime and magnesia within the boilers. Even with frequent flushing of the sludge or deposit from the boilers, scale or deposits of these salts materially shorten the life of boilers and fire boxes, to say nothing of the annoyance and interruption in service and the reduced length of life which these devices are subjected to in hard water districts. Fuel bills are also materially less with soft than with hard waters. Under some circumstances certain mineral salts in hard waters are decomposed in boilers and produce compounds which corrode the metal in a serious manner. It is needless here to enter into statistics which are available from a variety of sources, especially from the railroads, showing the various ways in which hard waters increase the expense of steam production.

For years the disadvantages of hard water have been offset in part by the use of "boiler compounds," that is, products added to the water in the boilers. In many instances this treatment has not only been of no benefit, but perhaps a detriment due to the boiler compounds being applied in an unsuitable manner either as to quantity or quality. In places where boiler compounds have been added under the advice of a competent chemist much benefit has resulted. This treatment does not solve the problem entirely as there results a considerable amount of precipitate and sludge within the boilers. These must be frequently removed in order to receive the benefit from this treatment. Notwithstanding the benefit received by the direct treatment of boiler waters under proper advice it seems to be a clear case that this is simply a step in the right direction, and that more complete and systematic treatment of hard waters for boiler use is advisable. This is evidenced by the repeated cases in the central West where railroads and large manufacturing establishments are proceeding with systematic softening of their boiler waters.

Mr. J. O. Handy, Chief Chemist of the Pittsburg Testing Laboratory, prepared a very comprehensive statement upon the purification of water for steam raising purposes for the International Engineering Congress held in St. Louis, two years ago. This valuable paper is to be found in the Transactions of the American Society of Civil Engineers, Vol. 54, Part A, p. 1.

In brief, it may be said that industrial softening plants date from about 1891, although there were a few small plants in this country prior to that time. It is during the last ten years, however, that the greatest development has taken place. The larger plants are usually of some well known make, such as the "We Fu Go," the "Ideal," or the "Kinnicutt." Interesting plants are found at Lorain, Ohio (*Engineering News*, May 17, 1900), Ensley, Alabama (*Engineering News*, July 3, 1903), and at Point of Rocks, Wyoming (*Engineering News*, May 15, 1902). The aggregate capacity in exact terms of the various industrial plants at present is somewhat uncertain, but it is safe to say that it exceeds 50,000,000 gallons daily.

For household usages people in hard water districts do not suffer so much inconvenience as might be supposed. Soaps

are available which contain unusual amounts of alkali, and while these are not wholly satisfactory for bathing purposes, they make the water much more serviceable. For laundry purposes the aid of washing soda is, of course, resorted to frequently. There is still another way of getting soft water, and that is to use rain water collected in comparatively large cisterns at each residence. In many cities throughout the South and central West a large portion of the households obtain "soft water" in this way. The inconvenience of this, except during periods of prolonged drought, is not very great, as water lifters are arranged to deliver the water throughout the households in the ordinary manner. The expense of dual piping is, of course, quite an item.

Mineral constituents of various hard waters differ so much that there is no simple rule by which all waters can be satisfactorily softened. On the contrary, unfortunate experiences on a small scale with industrial plants show that a certain style of treatment cannot be safely imitated regardless of its suitability for the water in question. After a water has been analyzed and the treatment adjusted to the requirements of the given case there is little occasion for the process to give trouble in the case of ground waters where the composition is quite uniform. The softening of hard surface waters is a more difficult proposition owing to their varying composition, and to obtain the best and most successful results such works should be operated under a certain degree of technical supervision.

The purpose of this paper is not to give a technical description of water softening practice in all of its details. It is desired simply to refer to some of the more important features upon which the treatment depends and to illustrate the same with lantern slides showing a few typical works. The plants illustrated are described very briefly, and references are given whereby other more important features in detail may be acquired.

As is well known it is the salts of lime and magnesia which make waters hard. These salts are divided into two classes which produce temporary hardness and permanent hardness, respectively. Temporary hardness is caused by the carbonates and bicarbonates of lime and magnesia. The normal carbon-

ates of these bases are very sparingly soluble in water, but when considerable carbonic acid gas is dissolved in water its power of dissolving lime and magnesia is vastly increased. The term "bicarbonate" refers to the carbonate held in solution with the aid of an equivalent quantity of carbonic acid. In connection with mechanical filters these carbonates and bicarbonates are spoken of as "alkalinity," and this expression is used considerably by water analysts. The old expression of "temporary hardness" refers to the hardness removed by a prolonged boiling of water which drives out the carbonic acid in the form of gas and leaves only the normal carbonates. This expression and this method of determining carbonate hardness are not very satisfactory, and are going out of use. Still another expression which is coming into use among those having to deal with water softening plants is that of "carbonate hardness."

Permanent hardness consists of sulphates, chlorides and nitrates of lime and magnesia. They are not affected by boiling the water, but upon concentration by evaporation, as in steam boilers, their solubility is such that they form a hard incrustation or scale. Analysts have recently referred to them as "incrustants." This is a more distinctive expression than "permanent hardness." Sulphates seem to occur in most waters to a greater extent than the other of these salts of lime and magnesia forming incrustants. In this way has risen the expression of "sulphate hardness." The sulphates of lime and magnesia are usually the most objectionable as well as abundant salts of this type. There is an exception perhaps to be made in the case of magnesium chloride. The latter compound, when calcium carbonate is not present in large quantities, may be decomposed upon heating with a liberation of hydrochloric acid which is corrosive to a serious degree.

Methods of water analysis from the standpoint of softening requirements have recently been much improved. They are described at length in the report of the Committee on Standard Methods of Water Analysis, Journal of Infectious Diseases, May, 1905.

To remove temporary or carbonate hardness it is universal practice to add a suitable quantity of lime water, according to the Clarke Process, discovered and patented in 1841. This

combines with the free carbonic acid and the "half bound" carbonic acid which holds in solution the majority of the lime. It causes the precipitation as a fine, granular solid of not only the lime originally present in the water in the form of a bicarbonate but also the lime which was added to the water. When a water contains its temporary hardness as lime salts and not as magnesia salts, this reaction takes place quite readily, unless it is attempted to carry the softening process too far. With magnesia carbonates, however, the addition of lime water causes the formation of complicated mixtures of carbonates and hydrates which are more or less soluble. It is, therefore, necessary to add lime to combine with the magnesia so that there will be formed an insoluble, gelatinous hydrate of magnesia.

Temporary hardness, incrustants or sulphate hardness require the addition of soda for their removal. Ordinary soda is the most suitable for this purpose. The sodium in the soda ash combines with the acid radicals in the lime and magnesia salts and form a precipitate of carbonate of lime. Ordinarily the salts of sodium thus formed, such as sulphates, chlorides, etc., while remaining in the water do not affect it for ordinary purposes.

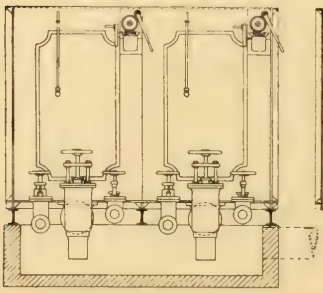
The means of accomplishing on a practical scale the softening of water vary widely, according to the type of water, as already indicated, and as will be further appreciated from the following references to works in practice.

Southampton, England.

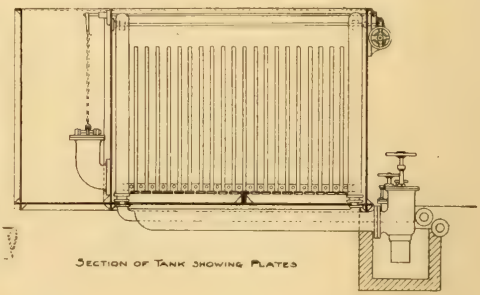
Southampton is situated on the southern coast of England, and has a population of about 75,000. For many years it has derived its public water supply from a series of wells and galleries in neighboring chalk cliffs. The water supply has been softened since 1888. It is treated with lime water to reduce the calcium carbonate, and after a short period of settling the water is clarified by passing through cloth filter presses. For some time filters of the Atkins type were used. The plant, as operated until about four years ago, was described at some length by Mr. J. H. Fuertes (*Engineering Record*, Feb. 4, 1899), and Mr. Handy (*Engineering News*, May 26, 1904). For the past three years or more the plant has been operated in an improved manner, especially with reference to a more satis-

factory control of the application of the lime water and the filtration of the partially settled effluent through cloth filters.

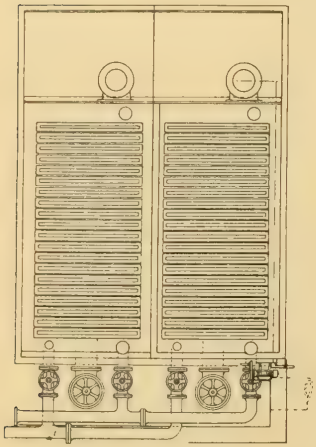
This plant has a nominal capacity of 5,000,000 Imperial gallons daily, and the water treated daily is about 4,000,000 gallons. High grade lime is obtained from quarries on the water works property and is burned in the department's own kilns. The lime water tanks are four in number, about 9 feet in diam-



FRONT ELEVATION



SECTION OF TANK SHOWING PLATES



PLAN

SOUTHAMPTON ENGLAND
WATER SOFTENING WORKS

PAIR OF 'HAINES' PLATE FILTERS
(PATENT)

EACH FILTER CONTAINING 20 PLATES GIVING A FILTERING AREA
OF 1080 SQUARE FEET

eter and 11 feet high with conical bottoms. The tanks are operated in pairs, each pair serving for a 12 hour-shift. At the beginning of each shift the attendant makes a milk of lime sufficient in quantity to serve during a 12-hour watch. After draining out the contents of the tanks used during the preceding watch he charges them with milk of lime and fills them with water to be used by his mate during the following 12-

hour shift. Softened water is delivered into these lime water tanks at the bottom by a pump attached to the low lift pump delivering well water to the softening plant. The lime water in this way is delivered in a quantity proportional to the volume of water to be treated, and is such that it takes about 1.5 to 2 hours to pass from the bottom of the lime tanks to the top where it overflows as a fairly well clarified solution of saturated lime water. There are no stirring arrangements in these lime tanks.

The hard well water with its proportionate quantity of lime water is thoroughly mixed at the entrance of the sedimentation basin which holds an average period of flow of about 40 minutes. There is a deposit of about 2 feet of carbonate of lime during each six months on the floor of the basin which is about 76 feet long and 44 feet wide. The water is very milky in its appearance as it leaves the settling basin and enters the cloth filters. The latter are a marked improvement upon the old Atkins filters and were designed and patented by the resident engineer of the works, Mr. C. J. Haines, M. Inst., M. E. As shown by the illustration each of the 10 filters comprises a tank 4 by 8 feet, with 500 sq. ft. of cloth filtering surface. Each unit is rated at a capacity of 500,000 Imperial gallons daily, equal to a flow of 0.83 U. S. gallons per square foot per minute. These filters are cleaned every 10 to 12 hours by moving up and down a pipe with jet sprinklers between each pair of filter cloths. It takes about 2.5 minutes to wash a filter. The cloths last about one year and prove a very satisfactory means of removing the carbonate of lime.

This water of Southern England contains about 18 grains of carbonate of lime per Imperial gallon, which is equal to a carbonate hardness or alkalinity of about 225 parts per million. The carbonate of magnesia is only about 0.5 grain per gallon, equal to about 7 parts per million. The incrustants or permanent hardness are so small that they are disregarded. This is the easiest type of water to soften as it does not call for a treatment to remove magnesia which forms a gelatinous, sticky precipitate which is more difficult to remove than the granular carbonate of lime. The carbonate hardness or alkalinity at Southampton is ordinarily reduced to about 80 parts per million. The softened water is very bright in appearance and

has no flat taste. The reaction is sufficiently completed in the 40 minutes so that the filtered and softened water contains no caustic alkalinity. In this respect the present lime water facilities are an important improvement over the devices operated prior to 1902. Mr. Haines states that his cloth filters are sold at about $8,000 per million Imperial gallons daily capacity.

Test Plant at Cincinnati, Ohio.

During the early part of 1899 some tests were made at Cincinnati, Ohio, on the use of lime for coagulating the turbid Ohio River water. These tests were made on a scale of 250,000 gallons per 24 hours and while not developed to a point to show great practical merit, they are of importance historically in showing one phase of the development of the use of lime in treating public water supplies in this country.

In this plant which was erected and operated by the Ohio Sanitary Engineering Company, lime water was applied to the river water in quantities to give excess of lime water from about 3 to 4 grains per gallon in the water after settling. Following a 12-hour period of sedimentation the water was coagulated so that it could be filtered at a rapid rate and produce a satisfactory quality as to clarification and the removal of bacteria and organic matter. The clay particles were coagulated due to the presence of the caustic alkalinity of the excess of lime water in a manner known to agricultural chemists for some time. This process is not to be confused with later treatments in which magnesia is utilized as a result of lime application to coagulate waters. The amount of magnesia in the Ohio River water at Cincinnati is too small to effect this result.

According to the Cincinnati evidence there appeared to be no economy in this style of treating the local water when due allowance was made for re-carbonating the effluent so as to eliminate the caustic alkalinity due to the excess of lime water. So far as known this process has not been developed beyond the state described by the writer in the Report on Water Purification at Cincinnati, Ohio, 1899, pp. 485 to 599.

Winnipeg, Manitoba.

The largest municipal water softening plant now in operation in this country is at Winnipeg, Manitoba. This plant has a capacity of a little less than 3,000,000 U. S. gallons daily. It was contracted for in the spring of 1899 in accordance with a

report made by Mr. Rudolph Hering to the Fire, Water and Light Committee of the City Council in September, 1897. The contract was awarded to the Pittsburgh Testing Laboratory and the technical details were largely developed by Mr. J. O. Handy, Chief Chemist, who has described the plant in a paper in the Proceedings of the Engineering Society of Western Pennsylvania, December, 1903, p. 705, and the *Engineering News* of May 26th, 1904.

This water is obtained from deep wells and contains in parts per million about 22 parts of free carbonic acid and 203 parts of carbonate of lime and 113 parts of carbonate of magnesia. Permanent hardness or sulphate hardness amount to about 173 parts per million but no attempt is made to reduce this by means of soda ash. Ordinarily the carbonate hardness is removed so as to leave a residual alkalinity of about 80 parts per million.

Lime is applied as a saturated lime water. The hard water enters a weir-box and by means of a series of proportional weirs any desired percentage of the hard water is diverted to a pipe leading to the lime saturator tanks. As the water flows to the latter it meets a stream of cream of lime in such volume as on an average is sufficient for the purpose intended. This cream of lime is dissolved as the water passes through the saturator tanks and leaves the latter as a fairly clear lime water. This arrangement is very ingenious and it insures the proper quantity of lime water at all times regardless of the fluctuations in operating the low lift pumps.

The lime water on leaving the saturators flows to a baffled channel where it is mixed with the main body of hard water. Thence it flows to the settling tanks which have a capacity of about 2 hours' flow and are operated on the continuous plan. In these tanks a majority of the carbonate of lime is deposited and the remainder is removed by passing the settled water through filter presses, specially designed, the details of which are recorded by Mr. Handy. This water owing to the relatively high amount of magnesia present is a far more difficult water to treat than the one at Southampton, England. This manifests itself by a tendency of the filtered water to deposit carbonate of lime in the high lift pumps and which is spoken of in general terms as "after reactions." To eliminate the latter

the water is carbonated by passing through the water a gas obtained by burning coke. The plant has been in operation since July, 1901.

Oberlin, Ohio.

The first softening plant in the United States for a municipal water supply was put in service on December 28, 1903, at Oberlin, Ohio. The plant ordinarily furnishes about 165,000 gallons of softened water daily and is described in detail by the superintendent of the works, Mr. W. B. Gerrish, in the Journal of the N. E. W. W. Assoc., Dec, 1905, p. 422.

The water is taken from surface sources and contains usually about 175 parts per million of carbonate hardness or alkalinity by far the greater portion of which is composed of lime rather than magnesia. The sulphate hardness ordinarily ranges from about 100 to 150 parts per million. There is much more variation in the hardness of this water from surface sources than in the case with ordinary ground waters. Lower temperatures in winter also add to the difficulty in completing the reactions.

This plant is also characterized as the first municipal softening plant in the United States in which the sulphate hardness is regularly removed by the addition of soda. The chemicals in needed quantities are weighed out every three hours and applied to the lime and soda tanks respectively. The strength of the solutions leaving these tanks in spite of mixing varies somewhat depending upon the quantity in the tanks. After the hard water receives the chemicals it is passed through a mixing box about 40 feet long in which are numerous baffles. After mixing it is passed successively through two reservoirs, the total capacity of which is equal to about 4 days' supply. The water is then passed through mechanical filters of the pressure type in the ordinary way. The alkalinity is said to be reduced ordinarily to about 30 parts per million. The long period of storage in the reservoirs is quite helpful, and it is said that no after reactions have been encountered to a bothersome degree. The cost of the softening works is given as $12,000. Quantities of applied lime range from 6 to 17 grains and of soda from 2 to 6 grains per gallon.

Freeport, Illinois.

The water supply of this town is obtained from deep wells which furnish a water which is very hard and which contains

considerable iron in solution in the form of a ferrous carbonate. Considerable trouble has been encountered from growths of crenothrix in the piping. To correct this trouble a 2,000,000-gallon mechanical filter plant was placed in service on October 13, 1903, and sufficient lime (2 to 4 grains per gallon) is applied to enable the iron to be practically removed. This reduces the harness about 13 to 15 per cent. according to Mr. Owen T. Smith, who described this plant in the Proceedings of the American Water Works Association for 1904, p. 148.

While this plant does not bear directly upon water softening it has an important bearing in an indirect way along lines which will no doubt be developed in the future.

St. Louis, Mo.

Since March 22, 1904, the turbid Mississippi River water used as a source of supply for St. Louis has been quite completely clarified by the use of iron and lime in connection with sedimentation basins holding an average flow of somewhat more than two days. Incident to the proper behavior of the sulphate of iron lime is used in sufficient quantities to cause precipitation of a part of the lime and magnesia in the river water. The reactions under local conditions and the method of applying this process have been described at some length by Messrs. Wixford and Wall in the Transactions of the American Society of Civil Engineers, Vol. 54, Part D, p. 236, and also by Dr. Snodgrass, City Bacteriologist, in the Proceedings of the American Health Association, Vol. XXX, 1905, p. 39.

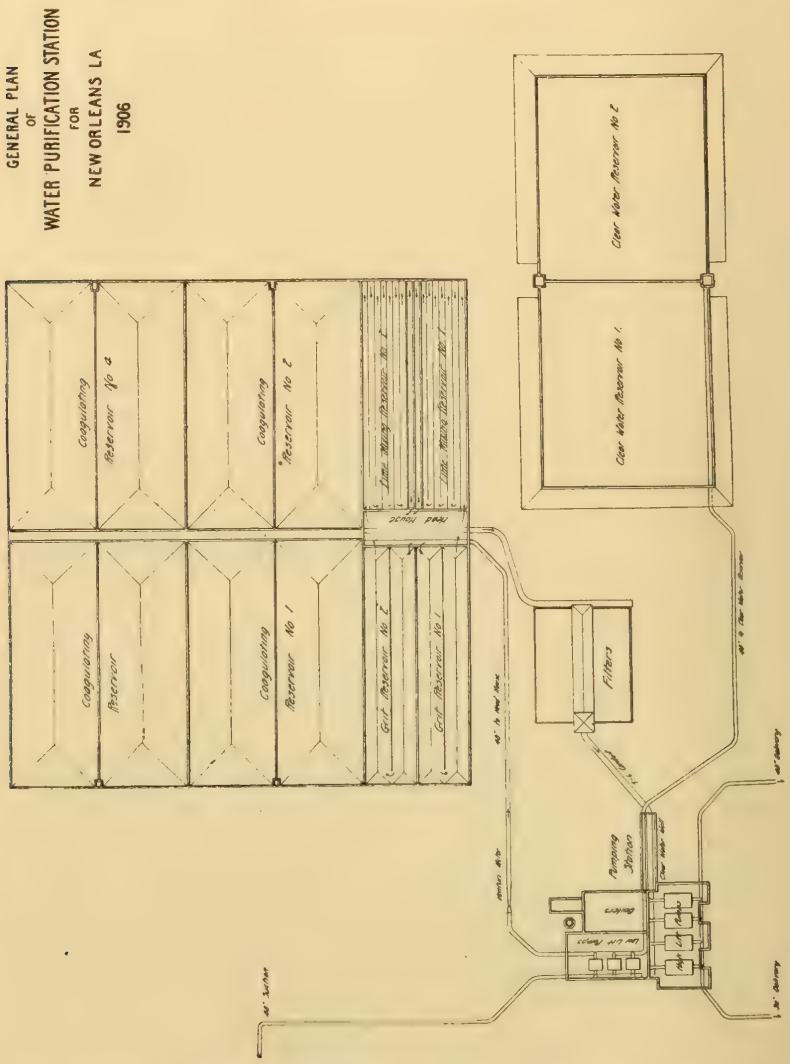
One of the most interesting features of the process consists in the method of applying the chemicals. This is done by adding them in dry solid form at 5-minute intervals to tanks in which water flows under conditions to insure a practically uniform rate of application of the chemicals.

The details as to results accomplished from the softening standpoint so far as known have not been published in full, but it is hoped that in the discussions at this meeting the data may be available from the St. Louis officials.

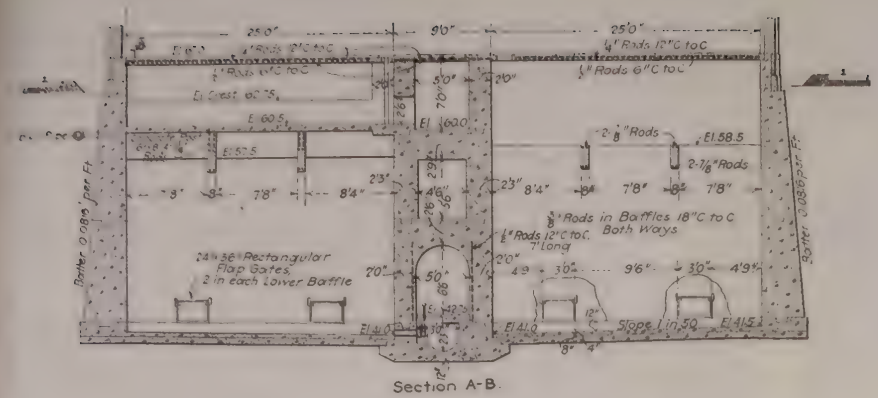
Columbus, Ohio.

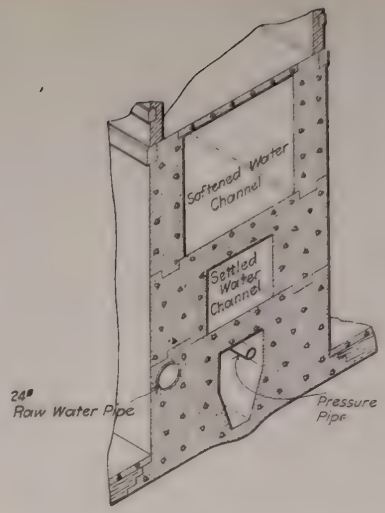
A water softening plant of 30,000,000 gallons daily capacity is now being constructed by the city of Columbus. It will treat the very hard and frequently turbid Scioto River water and

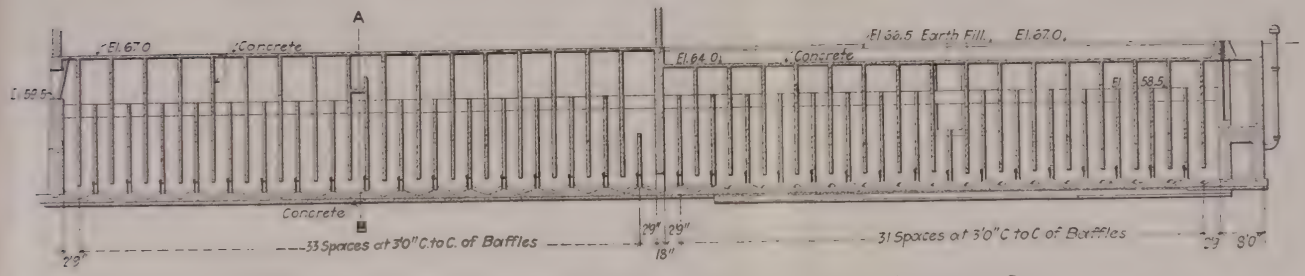
will remove not only bacteria, turbidity and carbonate hardness but also the sulphate hardness. Lime water will be applied as a saturated solution in a manner quite similar to the method at Winnipeg. After the hard water has received an applica-



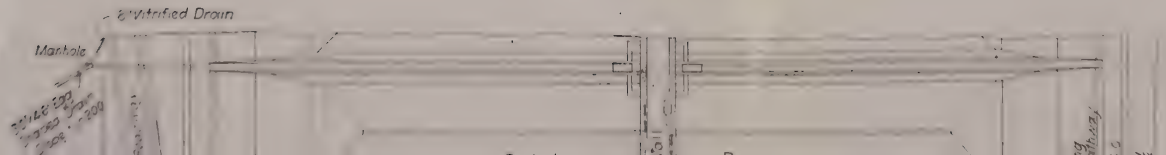
tion of lime it will pass through a highly baffled basin holding about one hour's flow. Shortly after the entrance of the water into this basin it will receive a solution of soda. The object of

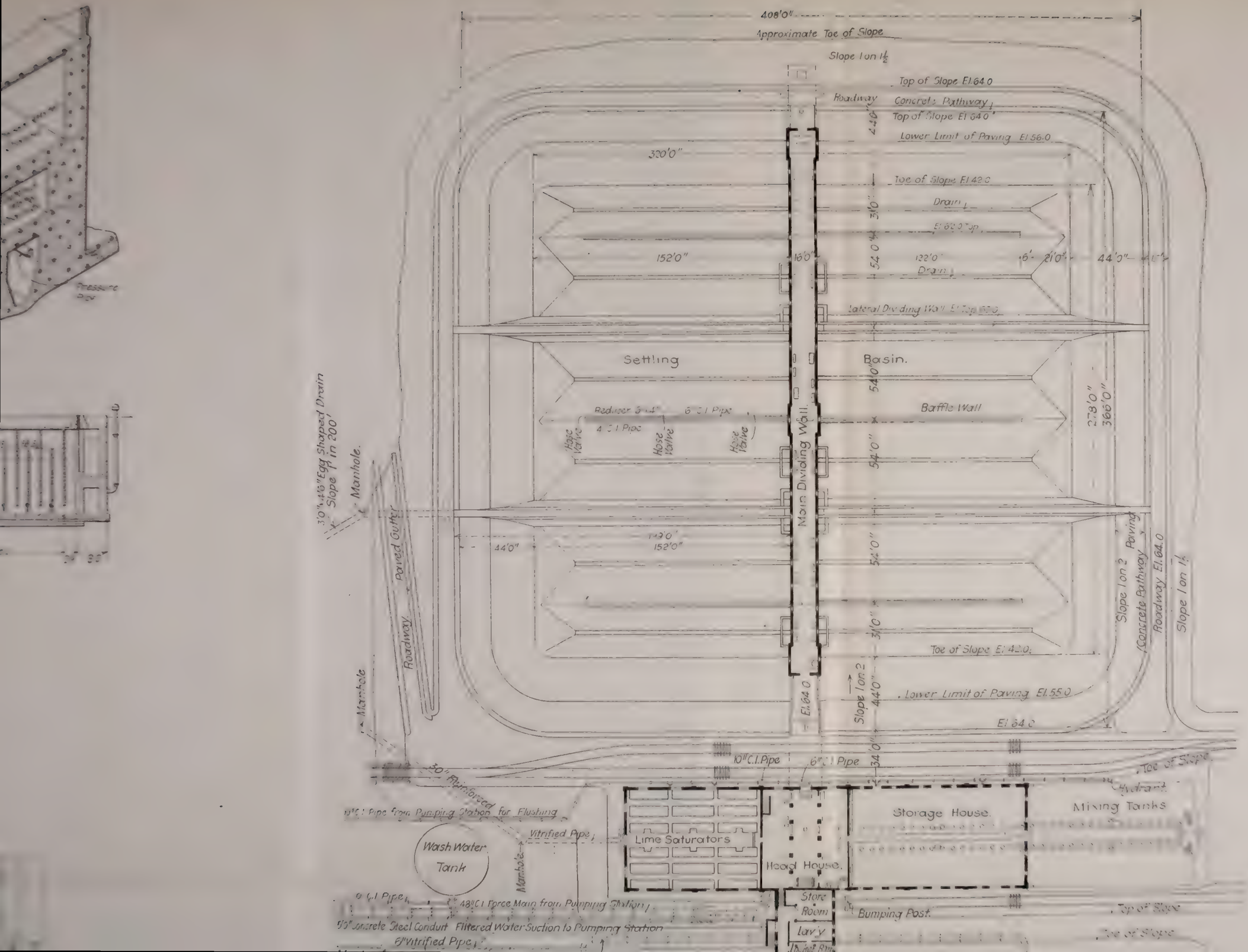


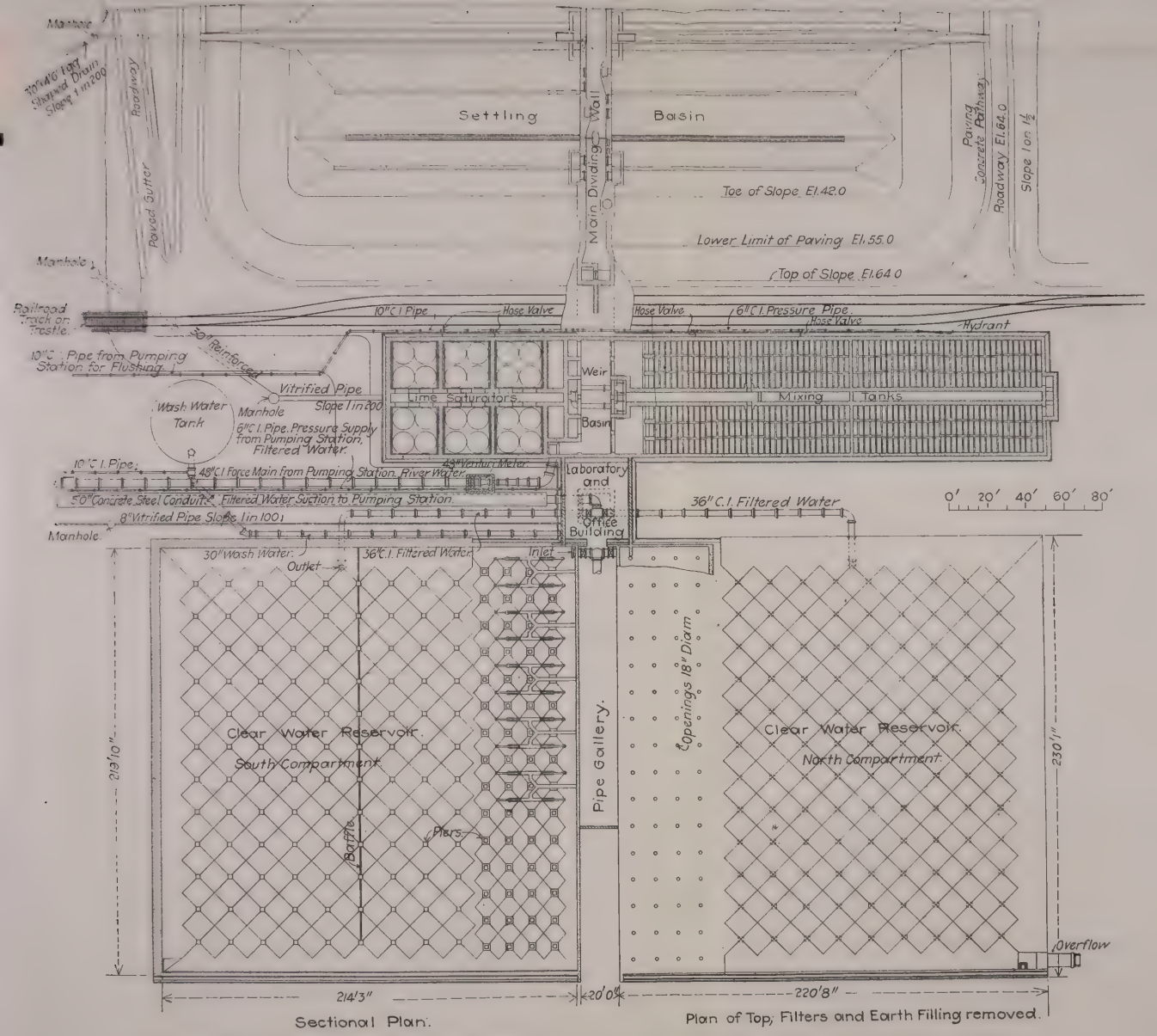




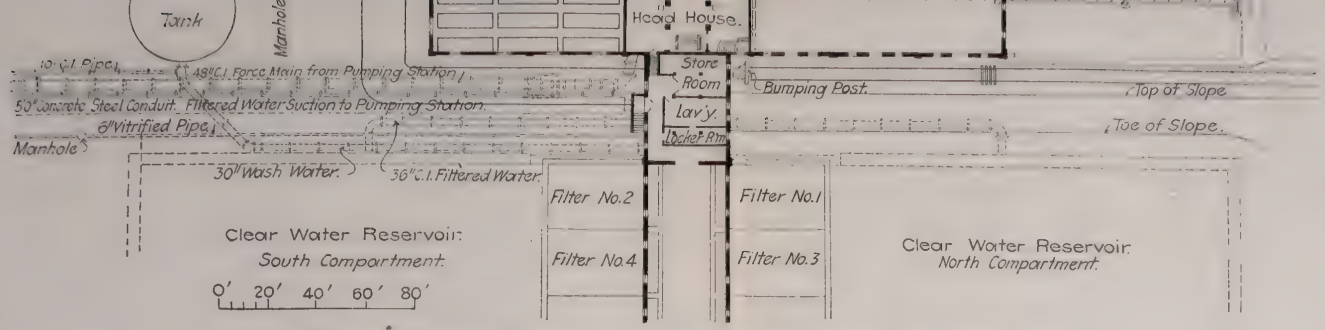
LONGITUDINAL AND TRANSVERSE SECTIONS OF MIXING TANKS, COLUMBUS, OHIO.



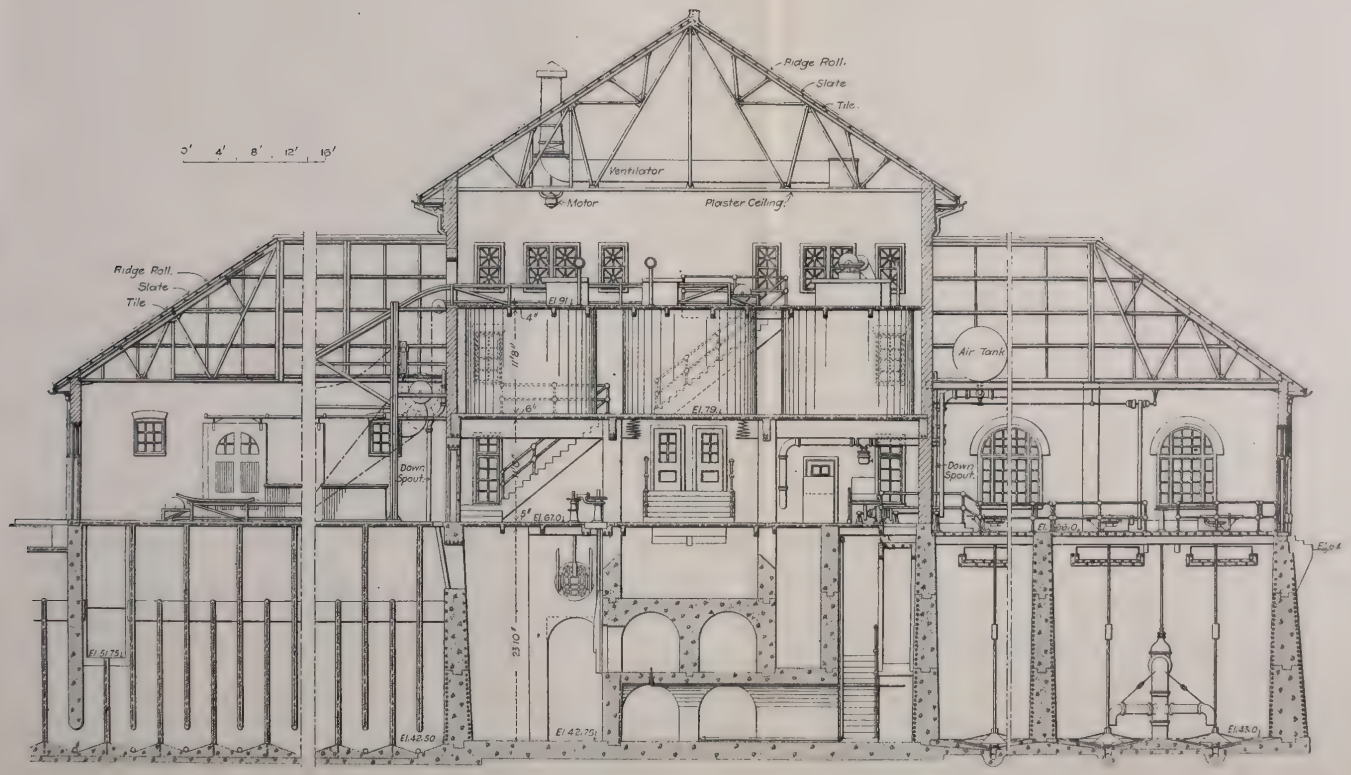

408'0"
Approximate Toe of Slope
Slope 1 on 1½
Top of Slope El. 64.0
Roadway
Concrete Pathway
Top of Slope El. 64.0
Lower Limit of Paving El. 56.0
320'0"
Toe of Slope El. 42.0
Drain
152'0"
16'0"
122'0"
Drain
6'
21'0"
44'0"
Lateral Dividing Wall
Settling
Basin.
Baffle Wall
Reducer
6" C.I. Pipe
4" C.I. Pipe
Hose Valve
Hose Valve
Hose Valve
Main Dividing Wall
54'0"
54'0"
54'0"
54'0"
278'0"
366'0"
3'0" x 4'6" Egg Shaped Drain
Slope 1 in 200'
Manhole.
Paved Gutter
Roadway
44'0"
152'0"
Slope 1 on 2
Paving
Concrete Pathway
Roadway El. 64.0
Slope 1 on 1½
Toe of Slope El. 42.0
Lower Limit of Paving El. 55.0
El. 64.0
Slope 1 on 2
44'0"
El. 64.0
Manhole
10" C.I. Pipe
6" C.I. Pipe
34'0"
Toe of Slope
Hydrant
30" Reinforced
10" C.I. Pipe from Pumping Station for Flushing
Vitrified Pipe
Wash Water Tank
Manhole
Lime Saturators
Hoist House.
Storage House.
Mixing Tanks
6" C.I. Pipe
48" C.I. Force Main from Pumping Station
5'0" Concrete Steel Conduit Filtered Water Suction to Pumping Station
6" Vitrified Pipe
Store Room
Lavy
Bumping Post.
Top of Slope
Toe of Slope



General Plan of Clear Water Reservoir and Adjacent Structures, Columbus, Ohio.



General Plan of Settling Basin and Adjacent Structures, Columbus, Ohio.



Section through Storage, Head and Saturator Houses, Columbus, Ohio.

this basin is to produce a thorough agitation with a view to complete the reaction in the presence of the resulting precipitates so far as feasible.

The water will then enter settling basins holding 12 hours' average flow. Arrangements are made by which the water may be withdrawn from these basins after varying periods of sedimentation with a view to applying the softened water to mechanical filters for final treatment without having to resort to the use of a coagulant. It is expected that sulphate of iron will be added during much of the time either for completing coagulation to prepare the water for filtration or for eliminating traces of caustic alkalinity. For the latter purpose it is proposed to convey raw water to the settling basin to be mixed with the softened water.

The most distinctive features of this plant are the very thorough mixing of the water with the chemicals (applied with automatic control) to complete the reactions as promptly as possible, the use of fairly long periods of sedimentation and of raw water and sulphate of iron to remove caustic alkalinity and mechanical filters for final clarification. The general features of this plant costing about $525,000, were described in the *Engineering Record* of February 24th, 1906. The works were designed and are being constructed under the direction of Mr. J. H. Gregory, Engineer in Charge. Messrs. Hering and Fuller are Consulting Engineers. The illustrations herewith are sufficient to indicate the more important features of the plant. A full technical description of the works will be given later by Mr. Gregory. An interesting account of the chemistry of the process under local conditions is given by Mr. A. E. Kimberly in the Supplement to the Journal of Infectious Diseases, May, 1905.

New Orleans, La.

Plans and specifications have just been completed for a 40,000,000 gallon purification plant at New Orleans for the purification and softening of the muddy Mississippi River water. Lime water will here be used to soften the water in a way to enable the precipitates of lime and magnesia to coagulate the water so far as practicable. Soda will not be used as the sulphate hardness of the local water is fairly low in

amount. The general features of this plant resemble quite closely that at Columbus, Ohio, although there are many important differences in the details. Some of the latter are very ingenious and it is believed that the plant will be unusually well equipped from a standpoint of controlling automatically its operation. These novel features were designed by Mr. Geo. G. Earl, the general superintendent of the new water works at New Orleans. Messrs. Hering and Fuller are the Consulting Engineers.

Speaking generally, the cost of chemicals for softening will ordinarily range from ½ to 1½ cents per 1,000 gallons, depending upon the hardness of the raw water, the price of chemicals and especially on the fact of whether or not soda is used.

There are a variety of ways by which the chemicals may be applied. It will require more experience on a large scale to determine which is the most convenient method and most readily subject to automatic control.

The thorough mixing of the chemicals with the water as provided in recent designs will apparently be helpful in several ways, including the reduction of "after reactions." Raw water and sulphate of iron applied to the water after settling in relatively large basins are feasible methods of eliminating caustic alkalinity and after deposits of lime. Whether or not they are the best means of accomplishing this cannot be told until differential data from practical operations are available.

Mechanical filters now seem to afford the best means for the final clarification of the softened water.

Discussion.

Mr. P. A. Maignen: The industrial systems of water softening, which have been introduced in this country during the last few years, are based on the use of reagents in a liquid form. These have not proved reliable and there is not, perhaps, one single installation of the kind alluded to where the engineer, inventor or contractor in charge of the plant would consider the treated water fit to drink. Sometimes an excess of lime, sometimes an excess of soda are used, at other times the chemical reactions are not complete and the water is not softened. Much, therefore, has to be done in the way of improving the industrial water softening plants, as at present installed.

The first water softening process invented appears to be due to Dr. Clark, a Scotch chemist, who lived some seventy years ago. He found that one part of lime water and nine parts of hard water (made hard by bicarbonate of lime or dissolved chalk) gave after sedimentation a satisfactory soft water. The hydrate of lime in the lime water absorbs the excess of carbonic acid which holds the carbonate of lime in solution as bicarbonate and when the two come together there is a precipitate of insoluble carbonate of lime. This system had been applied at Canterbury (England) twenty or thirty years before the installation of Southampton.

The first filters which were used at Southampton to clarify the softened water consisted of perforated zinc plates covered with canvas. These plates were arranged somewhat like those of filter presses. They were circular in form and the filtered water escaped through a shaft in the center of the plates. The plates or discs were revolved and brushes, between them, removed the sediment.

The quality of the lime (used in the wet process) varies from day to day. It quickly becomes air slacked and therefore is often of no use as a water softening reagent.

The means of pumping or feeding dissolved reagents now used have proved unreliable. By the dry method, on the contrary, the reagents are mixed together in a powdered form in those proportions which are suited to the particular require-

ments of the water under treatment. The powdered mixture is fed automatically to the water and no technical labor is needed to run the plant.

In England, where a large number of installations of this system are in operation, often the gardener or one of the servants is the only available labor; no complaint has ever been made of unsatisfactory results. The system is in use at the palace of the King at Sandringham, and at the country seats of many of the leaders in English society.

This system has become very popular, not only because it puts a stop to the incrustation of the hot water pipes and boilers, but, also, because the water is really softened and thoroughly purified. This improvement in the water supply has added considerable value to the property.

At Lancaster, Pa., the filter plant has a daily capacity of nine million gallons. The water is drawn from the Conestoga River by centrifugal pumps and steam turbines. It is raised and delivered direct to the water softening automatic device, without any sedimentation whatever. This device consists of a Poncelet undershot water wheel 6 feet in diameter and 4 feet wide. This wheel gives the necessary power to turn agitating machinery in four powder hoppers and in eight water tanks. The motion impressed by the wheel thrusts, through adjustable doors in the hoppers, the desired quantity of reagents and stirs, by mechanical arms, the water in which the powder falls. If the water comes in fast, the reagents fall in fast; if the water stops altogether, the supply of reagents also stops.

The quantity of reagents has of course to be varied according to the analysis of the water, thus, after a heavy rainfall the water is not so hard as at other times, and therefore the supply of powder is reduced accordingly.

After passing through the chemical or coagulation house, the water is led into a circular tank 50 feet in diameter and 10 feet deep with concentric baffles. It passes to another tank similar in size in which the chemical reaction completes itself and sedimentation begins. The water then passes through two 50-foot settling tanks containing rough preliminary filters. After this the softened water passes upward through ordinary scrubbers and downward through slow sand filters, with an artificial filtering membrane.

Water softening processes have something in common with the ordinary so-called mechanical filters. The chemical reaction or reactions must be perfect. If so, any kind of filtering system may be used, but if the chemical reaction or reactions are not perfect, then much more work is thrown on the filters.

The speaker is very glad that the subject has been so ably and strongly presented to the society by Mr. Geo. W. Fuller. It will certainly mark the beginning of an epoch in the art of water purification in this country.

The speaker wishes to emphasize the fact that the water which is properly softened is at the same time, sterilized; the chemical changes which take place during the reactions, which last two hours or more, are not favorable to the peace and comfort of the micro-organisms, in fact they are actually destroyed by these reactions, as has been shown by Dr. Burlureaux, of Paris.

The speaker has been asked by members of the association if he had any information on the physiological action of hard water. He is glad to say that he has.

There is not a single case of gout recorded in Scotland in thirty years. Gout and calculi are equally unknown in Ireland and Poland. This immunity is due to the fact that the water in these three countries is soft. Gout and calculi are, on the contrary, very prevalent in England, where the water is hard, particularly in what is known as the "stone counties" with its "petrifying" springs.

It is an error to say that lime is a necessary element in drinking water. There is sufficient lime in the solid food, in the form of phosphate of lime, which is assimilable, for the formation of bone and other tissues. The lime which is in the water is generally in the form of bicarbonate of lime (or dissolved chalk), and sometimes as sulphate of lime (or dissolved gypsum). These two lime salts are frequently associated together in the same water. These salts are impurities in water and they are noxious; thus at the Brussels Pharmaceutical Congress of 1888, the following resolution was formulated: "Waters which contain lime or other mineral salts, which are not naturally in the organism, form with the chyle, an abnormal medium for

hematosis (formation of blood). They fatigue the kidneys which have to eliminate them, and incrust the articulations."

The lime in hard water acts like alum. Both "coagulate" the food in the stomach.

When men, accustomed to high living, repair to certain thermal springs, at which the water is hard, they eat as usual a very large quantity of food, but this food does not profit them. It is not dissolved nor assimilated. The hard water which they take at the spring causes the food to remain solid, little of it passes into the blood. The patient, therefore, during a cure practically starves or thins his blood.

Dr. Moirôt, a prominent resident physician of Vichy, has stated in his works that "the abuse of Vichy water, at the beginning of a cure, has been more prolific in accidents than the use of mercury or iodine."

At other springs or resorts, such as Vittel and Contrexevile, where the water contains a considerable quantity of sulphate of lime, patients suffering from gravel or calculi are sometimes relieved. This fact would appear in contradiction with the theory advanced above. It is really not so. The irritation produced on the mucous membrane of the alimentary canal, by the excessive hardness of the water, is so great that the calculi are, as it were, pushed by a mechanical process (induced by the irritation spoken of) as you would push a stone forward with a handful of sand, projected with force.

Such water drunk as ordinary beverage would be dangerous and produce the very effects which it is supposed to correct when used as a temporary cure.

Hard water is bad for drinking, bad for cooking, bad for watering plants, horses and cattle. It is injurious to the skin, is unsuitable for all toilet purposes and very wasteful in the laundry.

Mr. C. A. Brown: The commercial side of water softening has received a great deal more attention in this country than has the softening of water for domestic municipal use. Some companies are making a business of softening water, and have built a large number of plants, one of which softens approximately seven and a half million gallons of water daily. Several other plants are very large considered as commercial

plants. The first work which I know of along this line was the We-Fu-Go Company at Cincinnati. They built a large number of plants and were almost universally successful. In fact, I do not know of any instance in which their directions were properly followed that satisfactory results were not obtained. Some very ugly waters were handled. The work done by the We-Fu-Go Company was perhaps directly responsible for the construction of the first complete softening plant for municipal use in the United States, that of Oberlin, of which Mr. Fuller has spoken. When the designs for that plant were made there was nothing to go on as far as municipal work was concerned, in this country, and but little information from abroad. In laying out that plant some rather nasty problems were met with, and in putting it into operation a great deal of trouble was encountered. For a while the citizens complained and said that they found every sort of taste in the water. I think Mr. Gerrish at one time had an inventory of about thirty-five different tastes and odors which the people reported they had found in the water, and which it is needless to say were largely imaginary. At the time the water, however, had a taste and an odor which was derived from chara. Later in the season when the growth had subsided, the water became acceptable for use.

Now the points that Mr. Fuller has brought up in the application of chemicals are of some interest with regard to the method of applying the chemicals and the results to be obtained. Of this we know a little more than we did some time ago. The Oberlin plant has given some results that were not when laying out the plant fully appreciated. First, the time which the water stands after it has been treated and before it is delivered to the consumer. Another point is the temperature of the water. If the water be very cold the reaction occurs very slowly. At Oberlin where there is sometimes during the low use of water six days' supply in the small reservoir, after the lime and soda ash has been added there is still a certain removal of the lime salts by a filter. For a while this proved a troublesome problem, but it has finally been overcome.

When the water is warmer precipitation occurs more completely and more rapidly. This apparently has been proven by

some experiments that have been conducted within the last year or so. The motion of the water also plays a certain part in the work. If the water is kept in a circular tank, in which it is caused to move in a slow whirl, the precipitation is apparently more complete, and the tendency towards reprecipitation is less.

The application of the chemicals must be exact if accurate work has to be obtained. If you do not get in enough lime you will not remove temporary hardness. If you do not get in enough soda ash you will not remove the sulphate hardness entirely. If you put in too much lime you will have a caustic reaction in the water which is highly undesirable. If you put in too much soda ash you will have soda left as a residue, which is equally or perhaps more objectionable.

In the Oberlin work, while the apparatus is somewhat crude for this purpose, the results obtained are very satisfactory. The variation there from day to day is very low. In a week's operation they frequently have a less variation than 10 p. p. m. in the filtered water; and in no case I believe in the last year or a little longer, have they had an excess of lime or soda in the water. This will show you with what exactitude a plant may be operated. The total hardness of the water is practically the total alkalinity of the water.

The application of the lime is the ugliest problem that we have to deal with. The soda can be made up in a standard solution and applied in such a way as to get pretty exact treatment; but the lime proposition is an ugly one. Inasmuch as only about 70 grains of lime can be put in the solution, you have to either apply lime water or else milk of lime. At Oberlin they use everything from a weak milk of lime to lime water, and the results even under those conditions are very satisfactory. In the last six months there has been some work in applying dry hydrate of lime. Very good results have been obtained in this way.

I think the indications are, from my point of view, that we will have the use of hydrate of lime pretty well established within the near future. Hydrate of lime offers certain advantages. It can be kept more readily and more perfectly. It can be handled equally as well, and it does not have to be slacked, it is already slacked. You can make a saturated solution of lime

water, or you can apply it in the form of milk of lime, just as you please.

A point that Mr. Fuller made in regard to the need of a strong pure lime is being experienced all over the country wherever lime is being used. At some of our mills we have great difficulty in securing a lime that will give us satisfactory results. What is needed is a lime that contains from 90 to 98 per cent of calcium oxide, quicklime—absolutely pure lime. With that sort of a lime better results can be obtained than from any other lime. With magnesia lime the tendency to re-precipitation is much stronger.

Just one other point: This question of purifying water or softening water for domestic use is one that I think has been assuming greater proportions than it ever has been supposed by the casual observer would be the case. Many of our waters through the West are almost unusable. I was in a city just a short time ago where it was almost impossible to create a lather with soap in the water furnished at that place. Those people can purify that water very satisfactorily by taking the proper means. I think that this question is one of interest to every man in this hall to-night.

Mr. F. A. W. Davis: What is the hardness of the water before you treat it, and what is the hardness after treatment—at the Oberlin plant, for example?

Mr. C. A. Brown: At the Oberlin plant it varies quite a good deal. At times the total hardness of the Oberlin water will drop to as low as 10 grains per gallon; at other times it will go approximately as high as 30. When it reaches these extremes it is only for a short time, just a few days, or a week—some such matter as that; but the total hardness of the softened water is approximately three grains per gallon. That is the total hardness. It frequently goes lower than that, and is sometimes higher; but it makes a water that is comparable to the ordinary rain water.

Mr. F. A. W. Davis: Is that hardness permanent or temporary?

Mr. C. A. Brown: Temporary and permanent, both.

Mr. Maignen: I am glad to be able to give Mr. Davis a typical analysis of water softened by my system:

BEFORE SOFTENING.

Temporary hardness	10
Permanent hardness	9
Total	19

Water contaminated with vegetable matter, unfit for drinking.

AFTER SOFTENING.

Temporary hardness	1
Permanent hardness	3
Total	4

First class drinking water.

The above is given in terms of grains per imperial gallon.

MR. MONFORT: With reference to the results of the softening process at St. Louis, I wish to present a few data derived from daily determinations of calcium and magnesium in both river and treated water. The full report will be published later, when the investigation has covered a longer period. For the present purpose it seems advisable to give a summary of results for May of the current year, as in some regards of most interest, although they are not representative for reasons now to be stated.

During this period one of the basins into which the water flows after treatment with iron and lime was cleaning, and therefore out of service, leaving but five basins for sedimentation—each of about 24 million gallons capacity—giving a total length of flow of 2,000 feet before passing into the lower pumping station. At this point also the basins were out of service for cleaning and alterations, so that sedimentation prior to sampling was confined to the five basins above mentioned. The rate of pumping was approximately 90 million gallons per 24 hours. During the month southerly winds on 19 days considerably accelerated the surface flow.

The water treated had a carbonate alkalinity varying from 94 to 148 parts per million, average 134, reckoned as calcium carbonate. This was reduced by treatment to an average of 42.6 p. p. m.

The total calcium in the river samples averaged 42.79 p. p. m., while the treated water averaged but 22.1 p. p. m.

The magnesium content of the raw water was reduced from 10.85 p. p. m. to an average of 4.108 p. p. m.

For the purpose of comparison it may be well to represent the amounts of calcium and magnesium (above reported as the weights of their respective ions) as equivalent alkalinity in terms of calcium carbonate. We have then

	River.	Treated Water.	
Hardness due to calcium salts....	106.9	55.4	p. p. m.
Hardness due to magnesium salts.	45.19	17.21	$CaCO_3$
	152.09	72.61	

The data given are for filtered samples of river water and unfiltered samples of treated water. Owing to the brief time of sedimentation due to the use of about half the regular system, the suspended solids in the treated water during May averaged 9.2 p. p. m., being about twice the June average, when the four smaller basins at the lower pumping station were restored to the system.

Mr. Bartow: It had not been our purpose to make any report of the work of the State Water Survey of Illinois at this meeting, but the paper by Mr. Fuller suggests that a brief preliminary statement of the work we are doing in the study of the municipal supplies of the State with reference to softening will be in order.

At Quincy there is installed a plant for the purification of the Mississippi River water. In 1905 the average net daily consumption was nearly 1,411,534 gallons, treated at a cost of $3.48 per million gallons, with lime and sulphate of iron. We have made two comparative analyses of the water before and after treatment, showing that the mineral content was changed as follows.

TABLE SHOWING COMPOSITION OF MISSISSIPPI WATER AT QUINCY, BEFORE AND AFTER TREATMENT.

Date of Collection,	March 9, 1906.		May 1, 1906.	
IONS	Before	After	Before	After
Potassium	2.7	2.7	2.3	3.1
Sodium	5.8	4.3	4.3	5.8
Ammonium			.1	.1
Magnesium	10.7	9.3	11.1	7.5
Calcium	30.0	18.4	29.2	17.9
Iron	1.2	.7	.3	.6
Alumina	5.1	1.2	.4	.1
Nitrate	2.4	3.0	.5	.5
Chlorine	2.5	1.5	1.5	2.
Sulphate	16.8	32.3	10.1	30.1
Silica	16.9	6.5	37.4	10.6
Silicious Matter			11.4	1.0

When the collection was made May 1, the treatment was 1.9 grains of ferrous sulphate followed by 2.2 grains of lime per gallon. In adition to the removal of all suspended matter, the calcium is reduced 40%, the alumina and silica nearly all removed. There is an increase noted in the sulphate because of the addition of ferrous sulphate.

At Moline, Illinois, the same treatment is used as at Quincy. The daily consumption is reported as 2,385,450 gallons, and the cost of treatment $5.50 per million gallons including labor and repairs. A comparative analysis just completed shows a reduction of nearly 50 per cent of ions of calcium and magnesium and a reduction of the residue on evaporation from 299.8 to 136.6 parts per million.

Several comparative analyses of the water at water works on smaller streams in the State (Fox, Kankakee, Vermilion, Sangamon and Little Wabash) have been made. We have found the soluble mineral content higher than that in the Mississippi River at the above mentioned places showing a greater need for softening. Since all the rivers of the State must be treated to remove sediment before they are available for water supplis, and such treatment requires the installation of settling basin and filters, we believe that the small amount additional

to make the necessary arrangements to soften such waters will be well expended.

Some ground waters within the State, especially in the drift areas, contain a large amount of iron and there is considerable trouble from crenothrix. The prevention of crenothrix and softening can be carried on at the same time.

It is necessary, as has been stated in the meeting to-day, to treat by purification in some way all the surface waters of the State except Lake Michigan, before they can be used in municipal supplies. There may be a few days during the year when they can be used without filtration, although even then they should be filtered. The ground waters of the State are harder than the surface waters, hence more need that they be softened. Some of these are troubled by crenothrix, as at Freeport, Illinois, where they have installed lime treatment to remove the crenothrix, and I understand the water is softened somewhat. In the case of waters free from crenothrix, it would be necessary to put in a complete installation for softening, for which the expense would be very much greater, and would many times prevent treatment.

MR. PATTON: What are the results of treatment with lime on the bacteria?

MR. MAIGEN: At Lancaster where the water is treated with lime, soda and sulphate of alumina, when the river is in flood, the bacterial results are as follows:

Raw Water .....9000 bacteria per c c.
Settled water after chemical treatment
and before filteration.....890 bacteria per c. c.
After passing through the Slow Sand
Filters ..... 30 bacteria per c. c.

MR. MONFORT: Speaking for St. Louis, on January 6, the reduction was 99.3 per cent.; the average reduction for last year from May, 1905, to May, 1906, inclusive, was 98.3. This is by softening treatment, using lime and iron.

MR. C. A. BROWN: At Oberlin the removal of bacteria can hardly be claimed entirely for the softening. In the plant as it was before the water softening was installed, about 90 per cent. was removed by sedimentation. They are getting on an average about 99.5 per cent. now. The actual removal by

sedimentation is about 98 per cent., taking the water from the time the chemicals enter it until after it passes the filters.

MR. REIMER: Certain figures of total hardness and temporary hardness have been given here that seem comparatively low and yet the water has been spoken of as hard water. I should like to know the experience of others with regard to what is called hard and what is called soft water. Our water we consider a very soft water, and yet it carries 5 grains of carbonate of lime per gallon. I should like to know how that should be rated. I have heard figures here to-night that would make it appear that we have a very hard water.

MR. MAIGNEN: In England water having six grains of lime per imperial gallon is termed soft water. Above that it is classed as hard.

MR. MONFORT: At Cincinnati the alkalinity varies from 21 to 66 parts per million; the total hardness from 53 to 102 parts per million. On the upper Ohio the alkalinity runs from 11 to 44 parts per million; total hardness from 30 to 70 parts per million. The maximum is reached in water from local streams which push out strongly from magnesian and lime stone regions after heavy rains. Dwellers along the upper river complain of a hardness of more than one grain per gallon (17 parts per million). Hardness is like the tariff "a local question."

A PICTORIAL APPEAL;—WATER-WORKS TOO.

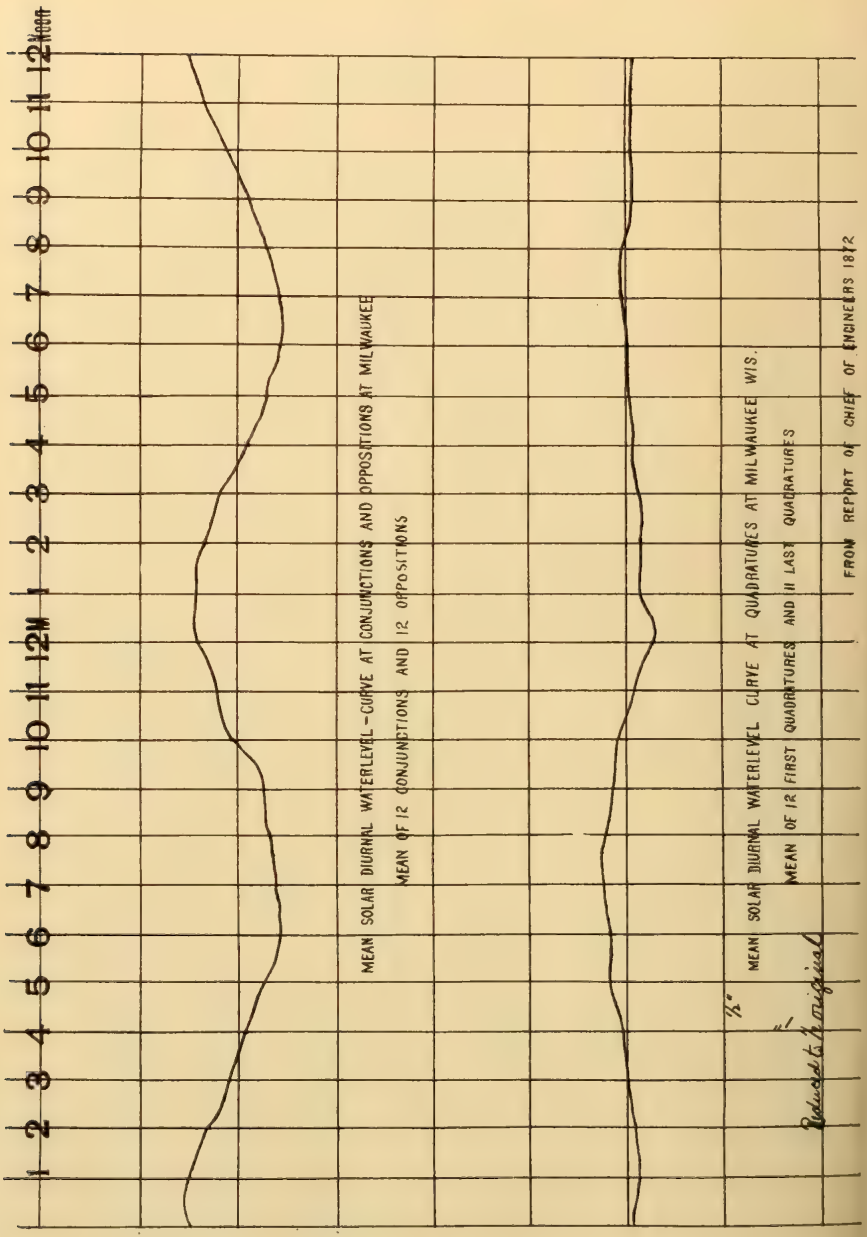
By H. F. Dunham.

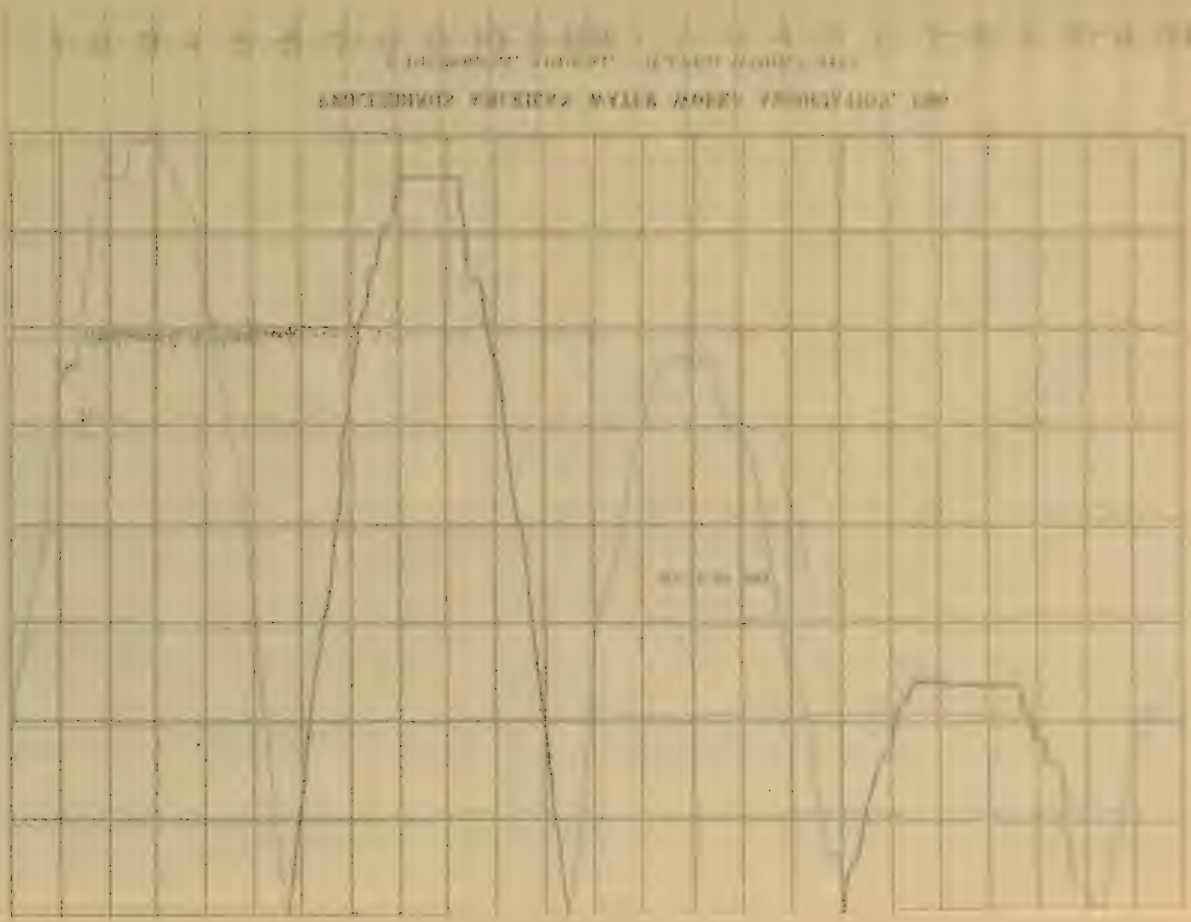
Changes in the level of the surface of the Great Lakes have been the subject of comment from quite an early period in their history. It is somewhere related that an accurate method of determining the actual height of the water at any given time and place is to excavate the sand near the shore, insert an empty barrel without a bottom and then take measurements from some fixed object to the water in the barrel. On account of the percolation through the sand this height of water varies with the stage of the water in the adjacent lake and is not influenced to any great extent by wave action. It has long been known that the variations in level are brought about by excess of rainfall over evaporation in the lake district, by variations in atmospheric pressure and by the force of the wind. In 1871 the Chief of Engineers of the Great Lakes was instructed to make an examination to determine whether the lakes were influenced by any tidal action or movement, and in the following year a report was made, based chiefly upon records kept at Milwaukee during the years '67 to '71. The method pursued was to read off from the records of an automatic tide gauge the height of water for solar hours and for lunar hours as well, and make comparisons tending to show whether tides occurred. The conclusions arrived at were summed up as follows:

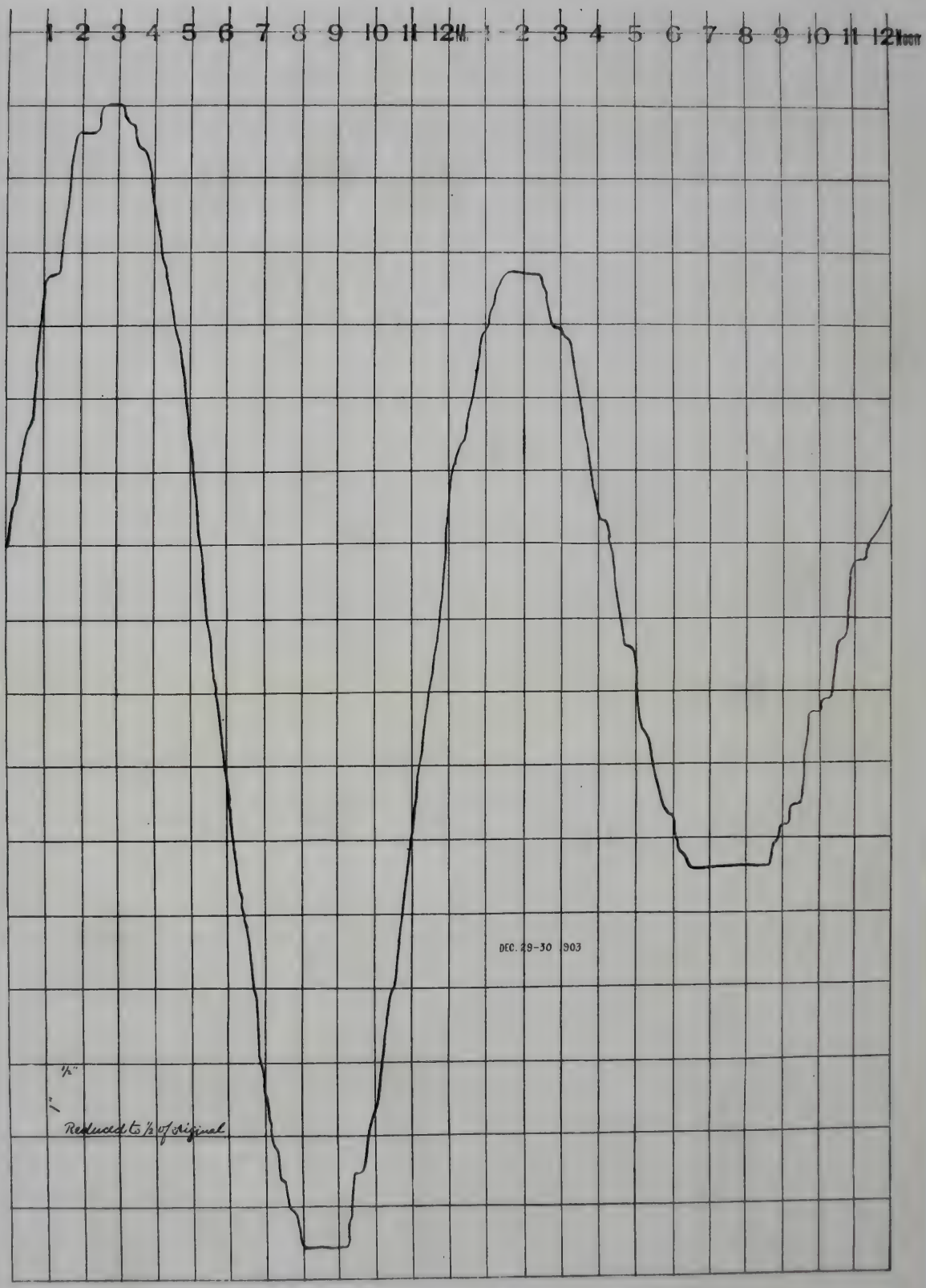
"On examining the solar hourly mean heights for the period covered by the record in each year (or curves plotted from them) a solar semi-diurnal tide was apparent of about four-hundredths of a foot, the tide following the sun's upper transit being considerably the larger. The known existence of a lake breeze at Milwaukee during the summer months at once suggested itself as a cause for this inequality."

Studies of the effect of the breeze seem to have confirmed the assumption.

"The examination of the lunar hourly mean heights for each lunation in 1867 (or of the curves plotted from them) showed a still more marked lunar semi-diurnal tide, its amount being eight-hundredths of a foot."

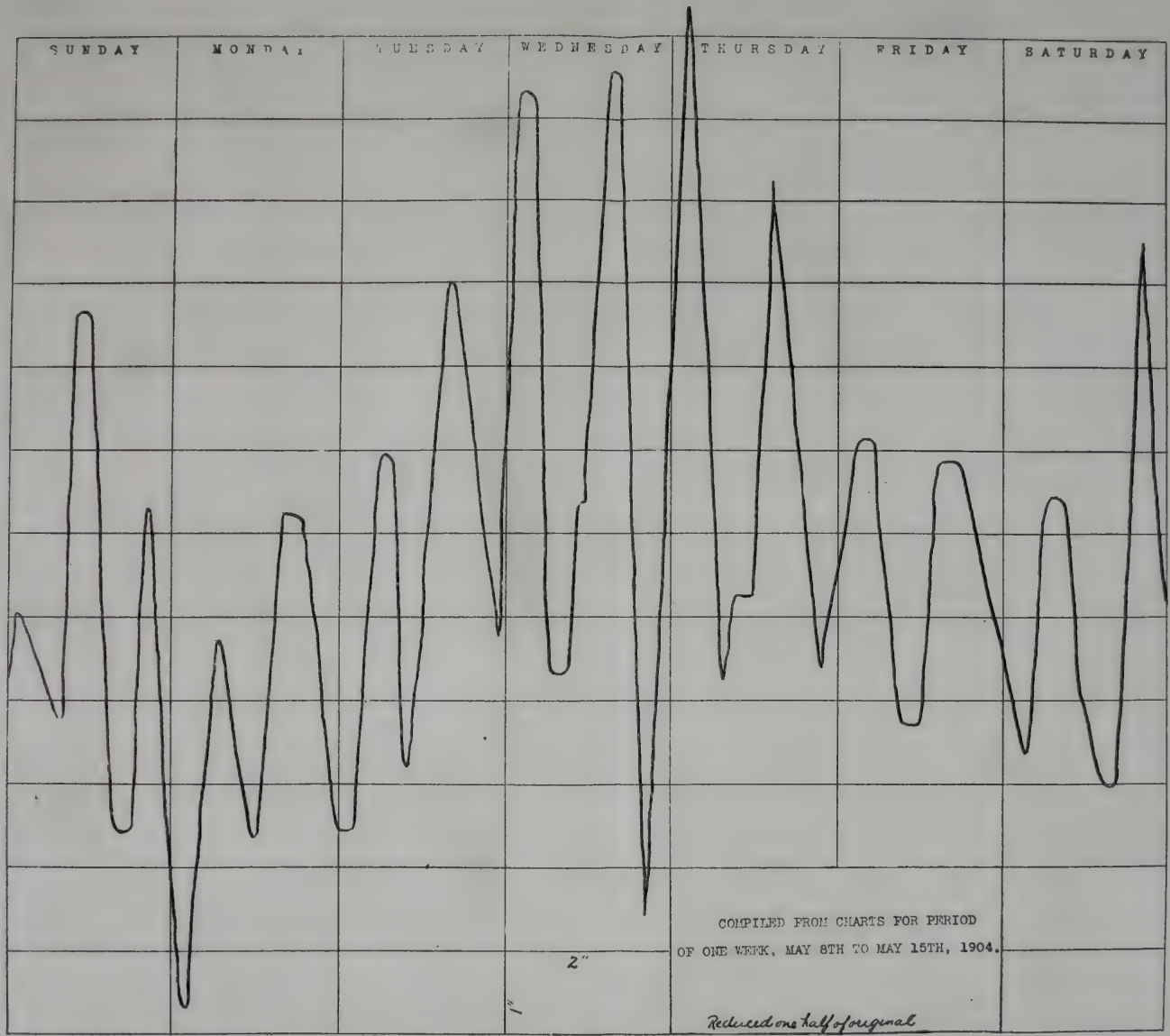

1 2 3 4 5 6 7 8 9 10 11 12M 1 2 3 4 5 6 7 8 9 10 11 12 Noon
MEAN SOLAR DIURNAL WATERLEVEL-CURVE AT CONJUNCTIONS AND OPPOSITIONS AT MILWAUKEE
MEAN OF 12 CONJUNCTIONS AND 12 OPPOSITIONS
MEAN SOLAR DIURNAL WATERLEVEL CURVE AT QUADRATURES AT MILWAUKEE WIS.
MEAN OF 12 FIRST QUADRATURES AND 11 LAST QUADRATURES
FROM REPORT OF CHIEF OF ENGINEERS 1872





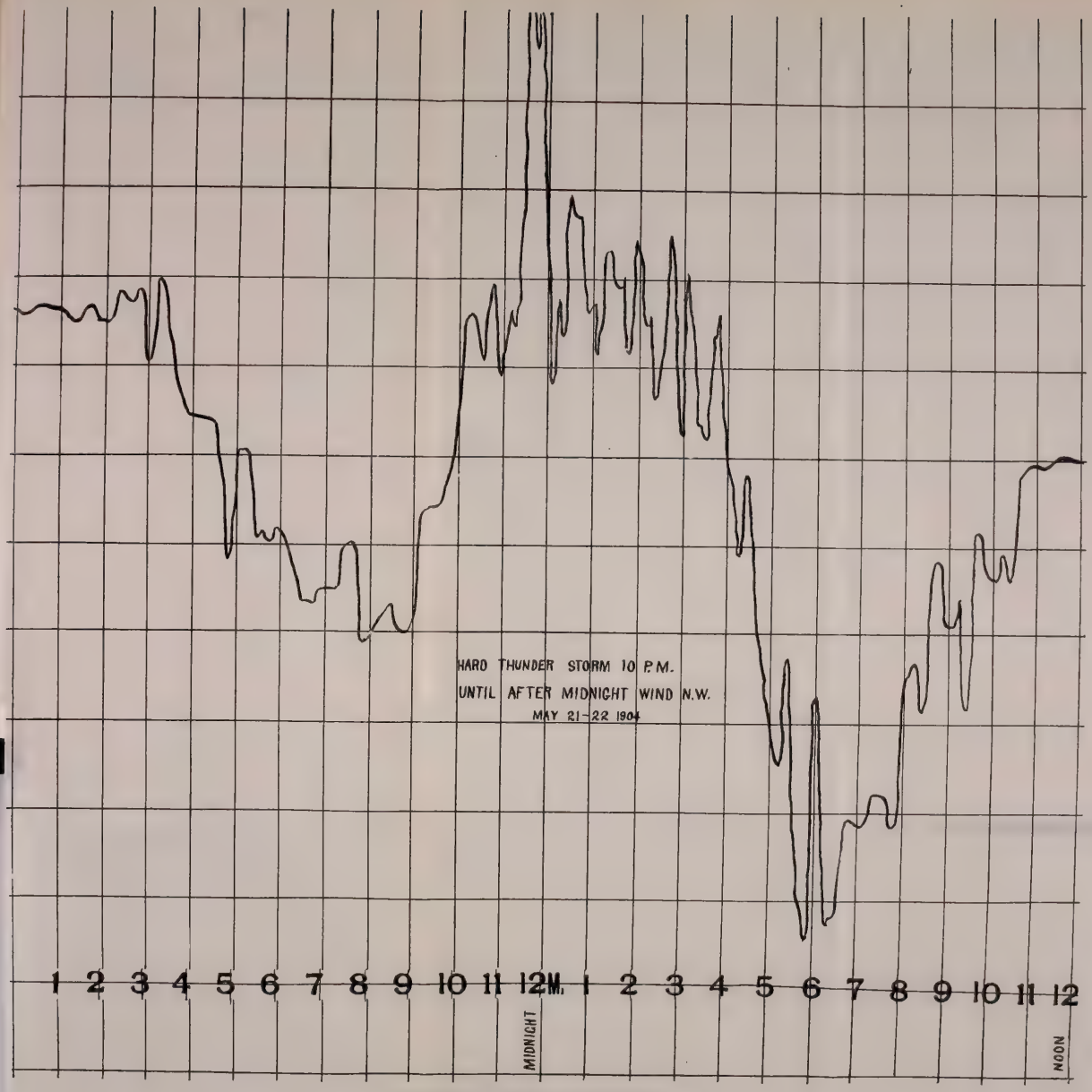
PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906

A PICTORIAL APPEAL: WATER WORKS TOO.



PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906

A PICTORIAL APPEAL:—WATER WORKS TOO.



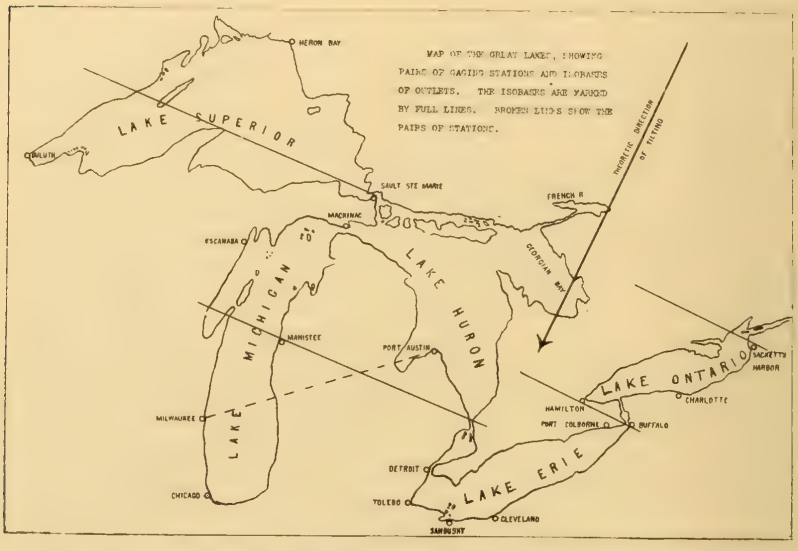
PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906.

A PICTORIAL APPEAL. WATER WORKS TOO

The type of automatic gauge used for these determinations is not known to the writer although some effort was made to ascertain its character, nor was its location closely indicated. For a considerable period after this date records of automatic gauges showing the more or less continuous movement of the surface do not seem to have been kept, although tables indicating the average height of water at various points during a series of years have been published from time to time in the survey of the northern lakes and from some of the late reports it would seem that more attention is now being given to the subject, and that several automatic gauges are placed at different Lake stations.

In the Smithsonian Report for 1898 there is a discussion of a movement of land and water in the Great Lakes region which does not depend upon rain fall, barometric pressure, tides or the force of wind. A theory is advanced, apparently based in part upon geological data derived from ancient beaches in the Lake Ontario and Lake Erie districts, which seems in the mind of the Smithsonian author to point to a gradual uplift or tilting on the entire plain upon or in which all the Lakes are situated. "The Theoretic Direction of Tilting" is shown by a line bearing S. 27° W., and passing through the easterly end of Georgian Bay. If the surface of the earth has been tilted in the direction assumed there would be an apparent depression of the surface of the water in the Great Lakes at certain points and a rise of the surface at other points. The principle involved is very simple. If a tank is filled with water to within say four inches of the top as measured on opposite sides, and then a few days or months later the distance to the water on one side is found to be two inches, and upon the opposite side five inches, it is evident the tank itself has been moved meantime; this would hold true whether the entire quantity of water in the tank had been increased or diminished. The attempt is made to refer the elevation of the average water level to permanent objects about the system of Great Lakes, and thus confirm the tilting theory. Many statements are collected and introduced in his discussion, tending to show the accuracy of the assumption. Comparisons between stations widely separated: Sacketts Harbor and Charlotte;

Port Colborne and Cleveland; Port Austin and Milwaukee; Escanaba and Milwaukee. The extent of the uplift thus outlined is finally reduced to common terms, and for a unit distance of one hundred miles, and for a time interval of one hundred years. The essential determinations, quoting from the Report, "do not comprise one that is free from doubt. Buildings and other structures on which the benches were marked may have settled. Mistakes may have been made in the earlier leveling, when there was no thought of subjecting the result to so delicate a test, and there are various other possible sources of error to which no checks can be applied."



But when these doubtful comparisons have been made the result is summed up in these words:

"Compared in this way the results are nearly harmonious, the computed rates of tilting ranging only from thirty-seven hundredths of a foot to forty-six hundredths of a foot per hundred miles per century; and in view of this harmony it is not easy to avoid the conviction that the buildings are firm and stable, that the engineers ran their level lines with accuracy, that all the various possible accidents were escaped, and that we have here a veritable record of the slow tilting of the broad lake bearing plain." From this data is estimated the

time that must elapse before the Niagara River dries up and the City of Chicago is submerged.

It might be well to note here just what is assumed, and what is proved. A large part of the level work was carried out very many years ago. Nearly all the data relating to the water levels depend upon conditions that are freely criticised by the author. Then the fact of tilting is assumed. Next, absolute uniformity of tilting over a section of the earth's surface corresponding to one twenty-fifth part of a 45° parallel is assumed, and upon this assumption is predicated the accuracy of the data which was before the subject of sharp criticism by the expounder of this theory. A clearer case of want of progress in any direction could hardly be cited. What geological evidence is to be obtained to show that uplifts extend uniformly over such vast areas? The lines of early equal elevation in the Lake Ontario beaches shown in the same Smithsonian paper indicate quite the reverse, and should lead us to think the ground at the east end of that Lake had changed its position with reference to the west end of the same Lake by several hundred feet. The general features of mountain ranges, slopes and foot hills are everywhere opposed to the assumption of uniformity of inclination between points so widely separated. It should occasion surprise that such unsupported conjectures find a place in publications devoted to the accumulation of facts and diffusion of wisdom.

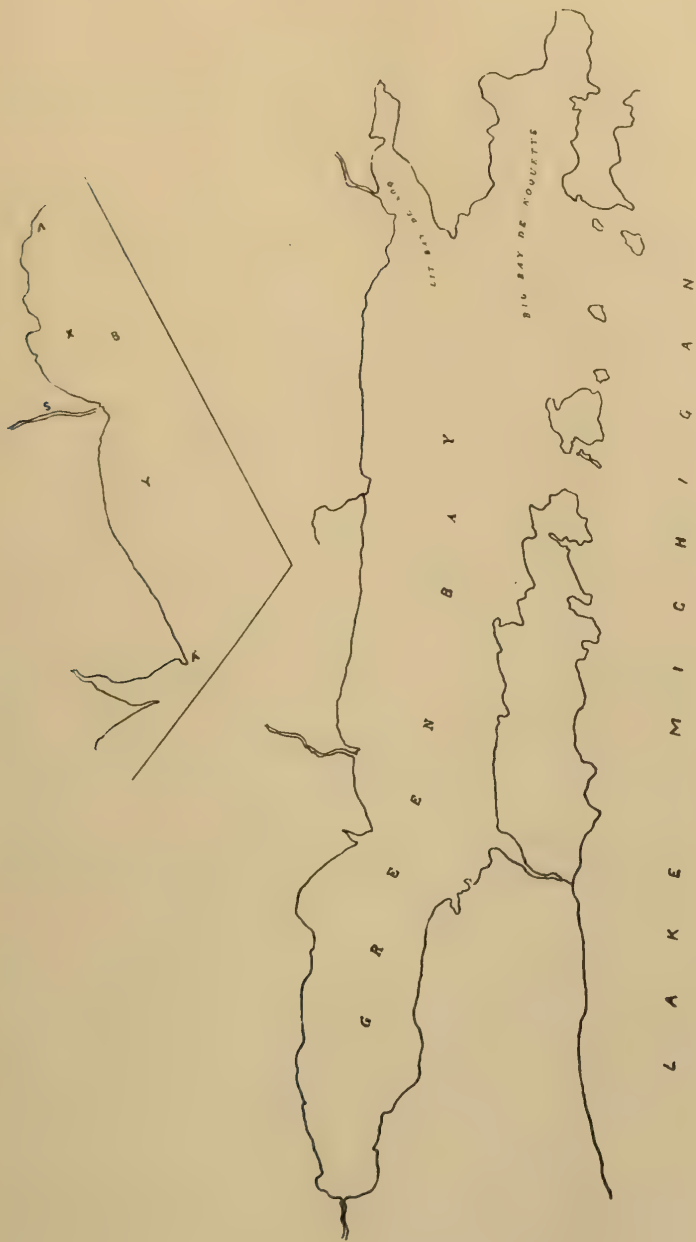
It is evident that the record from a tide gauge is valuable in proportion to its accuracy, and accuracy depends not alone upon sensitiveness, but upon sensitiveness and the absence of disturbances not connected with the rise and fall of water which is to be noted. A float that is affected by waves at a harbor station where boats are passing or where the discharge of a river may at times affect the height of water cannot give very satisfactory results.

The percolation plan through sand has some advantages, but the time required for the water to move in the sand becomes an element, and the highest and lowest stage when changes occurred rapidly would not be registered at all.

At a water works plant designed by the writer many years ago, at Menominee, on Green Bay, Michigan, there are three

lines of intake pipe; two intended for use for the ordinary supply and for ordinary fire protection, and the third for supply to condensers during an extraordinary fire or conflagration. As a matter of fact this third intake has never been used for supply. It extends about eight hundred feet to a depth of over twenty feet, where it terminates in a metal cylinder containing about eight thousand three-eighths inch openings. The line of pipe is twelve inches in diameter, and about twenty-five feet from the shore a one-inch connection was made and carried to a vertical sixteen-inch pipe at the shore line, so placed as to afford sufficient range for the rise and fall of the Lake or Bay water. Above the pipe is a home-made tide gauge, fashioned by the superintendent about a clock movement, and so arranged that the record is fixed directly by a pencil attached to a staff leading from the float. This avoids the use of levers or devices to diminish or to multiply the extent of motion. It is found that waves do not affect the record, but that any general rise or fall of the surface level is quickly recorded. In this most essential particular the gauge leaves little or nothing to be desired.

With a continuous sensitive record it should be expected that a tidal movement, if it exists, would be indicated by the line traced on the gauge cylinder without any interpolation or computation from heights of water at certain hours, and this proved to be the fact. The first daily record showed a rise and fall in about six-hour periods that could hardly be assumed a result of winds or changes in barometric pressure alone, although both of these forces doubtless affected the record in a larger proportionate degree than is true of ocean tides; and this fact might readily be anticipated. While the record of the first day offered little more than grounds for an assumption it was greatly strengthened by the second day's record, and when a week had passed the theory of probabilities would give a ratio in favor of tidal influence as against a similar repetition of atmospheric effects that might be stated as the ratio of the seventh power of two to one, or of two hundred and fifty-six to one; and when the same records were repeated for a month or half a year the evidence is substantially infinity to one or complete proof. The extent of the change may be fairly


LAKE MICHIGAN
GREEN BAY
BIG BAY DE NOUCHETTE
LITTLE BAY DE NOUCHETTE

averaged for the month of April, 1904, as a tide of forty-three hundredths of a foot per day instead of the three to four hundredths of a foot noted at Milwaukee as the result of averaging thirty-six lunations, although this differed but little from the calculations accompanying it in the report of the Chief Engineer.

It may be of interest to look for a moment at the opportunity offered by the shape of the Bay and its relation to Lake Michigan for effects similar to those at the Bay of Fundy. The Bay of Fundy has an area about three times that of Green Bay, while the cross section area at the entrance is approximately fifteen times as great. A natural inference would be that quite unlike or contrary conditions existed, and that the height of water in Lake Michigan proper must vary through a wider range than it does in Green Bay. The Bay has an average width of perhaps fifteen miles, and a length of about one hundred miles. The depth is but little more than one hundred feet, and the Bay is separated from Lake Michigan by a long strip of land, a part of Wisconsin, and by a number of small islands. It would seem from the cross section at the narrowest place that an increase in the height of water in the Lake would be followed by a less increase in the height of the water in the Bay. Gauge readings on the Michigan shore north of the entrance to the Bay would show the fact with reference to this point, but it is evident from the contour of the bottom and its character as well that strong currents prevail at the entrance to the Bay, and this fact is further attested by the name "Death's Door," and by navigators who experience difficulty from currents there in all seasons, and practically at all hours.

The velocity of the current under certain conditions can be roughly estimated. The area of the Bay is about fifteen hundred square miles. The area of the least section at "Death's Door," as indicated by Government charts, is about four million square feet. It is not unusual for a change in elevation at the rate of a foot an hour to be observed, and this gives an average velocity of eight thousand feet per hour through the narrow channels. The surface velocity would be much greater.

That like or similar currents produced under similar conditions of barometric pressure and tidal forces exist in the other

Great Lakes, and over areas larger than Green Bay, can be reasonably inferred. And it follows that where they do exist they do or may affect the quality as well as the volume of the water. Imagine a stream that widens out into a Bay with V-shaped shores, as it approaches a larger body of water; that the stream carries polluted water, and that from some point not far from the mouth of the river water is to be taken for a public supply. During the period of rise of water in the Lake the river water would be retarded and accumulated, and when the ebb or flow occurred the velocity of the current bearing the polluted river water would be increased, and pernicious effects might be manifested at greater distance from shore on account of these changes in level. Where a city discharges sewage into a lake at no great distance from the intake or source of water supply, the lateral or along-shore currents, due to changes in elevation of the water, are studied, and currents depend far more upon these changes than they do upon the regular flow of water to the point where the lake discharges.

The shore line or general shape of the body of water is also important, and may be even more important than the position or direction of harbor piers. This may be illustrated by a sketch in which a stream *S* discharges where the water rises and falls by reason of its relation to a larger body of water. *AA* shows the shore line, and *B* the outlet for the bay water. It might at first appear that an intake at *Y* would prove more satisfactory than one at *X*, both being the same distance from the mouth of the river; but in fact for about one-half of the time, that is, while the water is rising, the course of the river would be turned directly toward *Y*; and during the other half or corresponding period, when the water was falling, the current would be from the river mouth toward *B*, with little tendency to flow toward *X*, while the usual induced lateral currents or eddies would actually be helpful in bringing water from a distance to the intake located at *X*.

But very exact or definite conclusions should not be based upon records from one point alone, or from many points for only a short interval. The Appeal in the title of this paper was intended to cover a suggestion or petition to superintendents

in charge of lake supplies to take advantage of the favorable opportunity which they have to keep an accurate automatic record of the elevation of the water. The merit in the arrangement described lies in making a record which shows the rise and fall of the surface, and is not influenced by wave action. There is no reason to conclude that a twelve-inch intake pipe eight hundred feet long is necessary for this purpose. A comparatively small and short pipe would no doubt give equally good results. Where condenser water overflows there is no trouble about the winter service. The cost of the clock movement is very little. All else is covered by the spare time of the engineer or his assistant. The recorded information with its relation to aneroid readings is of great interest. It is to be supposed that the water works station has a rain gauge and a mercury barometer, or an aneroid, almost indispensable for weather determinations, especially if read at the same hour the Weather Bureau instruments are read. But if it could be rightly understood, one of the Great Lakes is more sensitive to atmospheric pressure than a high grade instrument, and delivers reports from more than one distant point while the barometer gives merely local information. This is well shown by the record during the thunder storm, and by that of December 29, 1903, and by the fact that the pencil of the gauge was carried above the cylinder at Menominee when the water went down in Sandusky Harbor to a point lower than had been previously recorded. And then the encouraging or optimistic effect—to return to the Smithsonian writer. If he has shown that earth works more than common people believe, it may be possible to show that water works more, too, and it would bring good cheer to us all if his figures could be revised and the time extended for visitors to enjoy the beauties of Niagara before the river dries up; and for the people of Chicago to further exhibit their sand before it is submerged by the waters of Lake Michigan.

This paper was intended for the meeting of the Association held last year in a Western State where a large number of superintendants from Lake cities were present. It was not presented then and comes up now out of its proper longitude or field of special interest.

MR. DUNHAM: Since this paper was prepared there have come to my notice one published statement and one publication that may have a little interest in connection with the subject of the paper. The published statement is from a work on the Geology of Pennsylvania and is mentioned because it seems to oppose the ideas outlined in the Smithsonian Report and because that State has a bit of shore line on the System of Great Lakes. This paragraph evidently indorsed by Prof. Leslie when he was State Geologist is as follows:

The great diversity in the direction of the axes of the several rock folds in the field all presumably of contemporaneous formation, is of itself a refutation (if any were still needed) of the old ideas of the universal parallelism of axes of the same age; as if there were something of a crystalizing tendency in all the globe as a whole with world wide planes and great circle lines of activity. On the contrary the folding would seem to have been guided simply by the lines of least and greatest resistance, by the thickness and cohesion of the beds folded and by the prominence and firmness of the older ridges that could resist and bound the movement of the more recent rockbeds lying between them. . . . The prominence and firmness of the older ridges depend in the same way on like conditions of an earlier period and on the subsequent folding of the ancient rockbeds then formed.

With this on record there may be a chance to note which writer's view is sustained by the earthquake and the subsequent checking up of coast survey elevations.

The publication referred to is entitled: "Currents of the Great Lakes as Deduced from the Movements of Bottle Papers During the Seasons of '92 and '93," by M. W. Harrington, Chief of the Weather Bureau. The object of the publication is set forth in the first paragraph:

Early in 1892 the Weather Bureau published a wreck chart of the Great Lakes prepared in the winter of '91 and '92. The wrecks noted on this chart were only those due to meteorological agents and a striking feature of the chart was the clustering of wrecks in certain parts on the surfaces of the Lakes. This suggested that unknown currents might play a considerable part in wreckage and steps were at once taken to get some idea of what these currents are.

In another paragraph reference is made to popular proverbs. These two are from Michigan:

The Great Lakes and Straits are good indicators of wind.

The current will always run the way the wind is going to blow from six to twelve hours before the wind comes.

The currents in the Great Lakes move very fast when thunder clouds are in the sky.

There follows a third but it does not state to which Lake it applies:

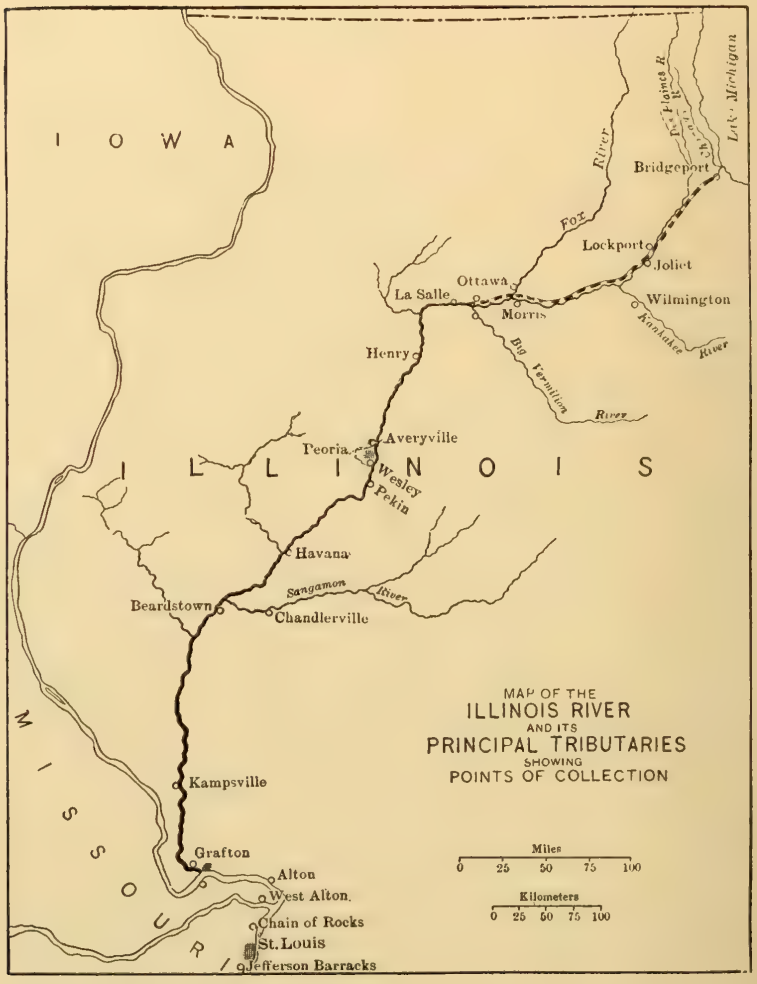
If the water falls on the shore of the Lake whichever side, the wind will be off shore in a few hours. If the water rises it will be on shore.

If this were to be literally applied to conditions represented by the slide showing the rise and fall of water in the month of May, 1904, there would be a frequent and uniform change in the direction of the wind that should be generally noticed.

The Bureau's method of determining currents was to provide Lake captains with bottle papers and directions to throw them overboard at more or less well-defined points. When picked up the inclosed paper was to be marked with the time and place of finding and sent to the Bureau. The bottles were about twenty centimeters in length and six in diameter and with about one-fifteenth part of the volume exposed above the water. Having regard only to Lake Michigan it appears that of the bottles floated in this Lake a total of 198 were recovered at the end of 1893. Elsewhere in the volume it is stated that from five to ten per cent. of the total number of bottles was picked up, so that it would seem that in the neighborhood of two thousand bottles had been floated in the Lake. The slide is a photograph of a map in the volume mentioned, showing Lake Michigan. It also shows the outline of one of the bottles and the angle at which it floats. The lines upon the map are supposed to indicate the courses followed by the bottles and if correct they would show a very marked current toward the north on the east shore of the Lake. It is clearly stated in the text that nothing is positively known as to the course pursued by any bottle from the time it was thrown overboard until it was picked up and nearly all of them were picked up on shore. One might question the accuracy of any theory upon which a bottle thrown overboard in the eastern part of the Lake and found on the eastern shore only twenty miles away should have a mapped-out circular course of 150 miles or so between the place it was put afloat and the place where it was found.

All of these lines however upon the map do indicate that some reason exists or is supposed to exist for a current to the south on the western shore of Lake Michigan and a current to the north along the eastern shore. The Bureau publication does not advance any explanation beyond the general inference that the currents are due to the force and direction of the wind and several tables are introduced to show the direction at different seasons of the year. The writer's experience with mid-depth floats leads him to believe that a bottle of the proportions shown with a fifteenth of its volume above the surface would in many cases move much faster than the current for the reason that being a unit not subject to change in form as water is at the crest of a wave or elsewhere, it would be often subjected to the full force of the wind over a large part of its surface and thus be sped along. The writer believes that a mid-depth float having an area of more than three square feet was led or influenced in its course by the action of the wind upon a part of a cork that did not exceed one cubic inch in volume. Such conclusions however are hardly susceptible of exact proof. If further observations of the rise and fall of water at different points about the Lake confirm the inference with respect to tides that affect the Lake and Lake Huron as well as Green Bay, it would then be reasonable to hint as further explanation that the tidal movement itself carried a large volume of water in a westerly direction and caused it to impinge upon the west shore of the Lake where the general outline would tend to establish currents to the south. This would be further confirmed if it were discovered that a considerable volume of water passed regularly through the Straits of Mackinaw where the least cross-section is probably in excess of a million square feet. The Straits have a width of more than three miles and a maximum depth of over 220 feet. A not very rapid motion of a body of water having such a cross-section would be continued without any added impetus for a long distance and the west shore of the Lake is nearly a hundred miles away with deep water intervening where it would be expected that a tidal movement should increase.

If it were found that observations indicated the regular rise and fall already observed at Menominee, they might be taken as evidence that the Bureau's discussion and representation of the currents was near to the truth although based upon entirely unlike premises.


IOWA
ILLINOIS
MISSOURI
Lake Michigan
Des Plaines R.
Chicago R.
Fox River
Bridgeport
Lockport
Joliet
Ottawa
La Salle
Morris
Wilmington
Kankakee River
Big Vermilion River
Henry
Averyville
Peoria
Wesley
Pekin
Havana
Sangamon River
Beardstown
Chandlerville
Kampsville
Grafton
Alton
West Alton
Chain of Rocks
St. Louis
Jefferson Barracks
MAP OF THE
ILLINOIS RIVER
AND ITS
PRINCIPAL TRIBUTARIES
SHOWING
POINTS OF COLLECTION
Miles
0 25 50 75 100
Kilometers
0 25 50 75 100

THE CHICAGO DRAINAGE CANAL CASE.

WM. P. MASON.

The Chicago Drainage Canal is a cutting 28 miles long, extending from the south branch of the Chicago river at Robey street, Chicago, to the controlling works at Lockport. These works consist of a movable "bear-trap" dam and seven lifting gates, each of the latter possessing an opening 32 feet wide. The cross section of the canal varies somewhat in different sections, but it may be described as having in the "full sized" portion a bottom width of 202 feet with a minimum depth of water of 22 feet. Water from Lake Michigan enters the canal with a volume of some 250,000 to 300,000 cubic feet per minute, reverses the current of the Chicago river and flows over the dam into the Des Plaines river, a tributary of the Illinois, which latter river then flows some 300 miles to its junction with the Mississippi.

Work was begun on the canal September 3, 1892, and water first flowed over the bear-trap dam on January 17, 1900.

The cost of this great work was about 43 millions of dollars, and such expenditure had for its object the protection of the water supply of Chicago from pollution by the sewage of the city; it being well known that, under the conditions formerly obtaining, the water drawn at the intakes was contaminated by the ever increasing volume of sewage poured into Lake Michigan by the sewer outfalls along the shore.

As a measure of the betterment in the quality of the lake water resulting from the opening of the canal, let the following facts, taken from the Bulletin of the Department of Health of Chicago for May 19th, 1906, speak for themselves: "During the six years immediately preceding the opening of the drainage channel there had been a total of 141,473 deaths in Chicago, an average of 23,579 each year, a rate of 16.2 per thousand of the population. During the subsequent six years, ending December 31, 1905, there was an annual average of 26,373 deaths, a rate of 14.31 per thousand, or a reduction of 11.7 per cent. in the general mortality.

"Deaths from typhoid fever in the pre-channel period were 3,275, an annual rate of 37.6 per 100,000 population. Deaths from typhoid fever during the channel period were 2,937, an annual rate of 26.9 per 100,000 population, a reduction of 29 per cent.

"Deaths from diarrheal diseases in the pre-channel period 16,669, an annual rate of 192.9 per 100,000 population. Deaths from diarrheal diseases during the channel period 13,609, an annual rate of 123.1 per 100,000 population, a reduction of 36.9 per cent.

"The total cost of the channel up to December 31, 1905, had been less than 50 million dollars.

"The figures given above of typhoid-fever and diarrheal-diseases mortality show a constructive or potential saving of 8,966 lives, which, at the legislative valuation, represents a total of $89,660,000."

Fearing that damage to her water supply would result from the operation of the Drainage Canal, the city of St. Louis, acting through the state of Missouri, brought suit in the Supreme Court of the United States, with a view of stopping the diversion of Chicago sewage into the Mississippi valley and the "CHICAGO DRAINAGE CANAL CASE" was the result.

Technically this case is known as "The State of Missouri (complainant) vs. the State of Illinois and the Sanitary District of Chicago (defendants)."

The issue having been between two states, the Supreme Court of the United States possessed original jurisdiction and the hearing was had directly before that body without previous consideration by a lower court.

The bill of complaint, which was filed by Missouri, set forth that Chicago had cut through the natural divide separating the water shed of the Great Lakes from that of the Mississippi river, had abandoned her natural drainage outlet via the St. Lawrence and had substituted therefore the waterways leading to the Gulf of Mexico. It was claimed that by reason of such action the sewage of upwards of one and one-half millions of people, and amounting to about 1,500 tons of sewage material per day, would poison the waters of the Mississippi river, render them unfit for domestic use and create a direct

and continuing nuisance which would endanger the health and lives of the inhabitants along the Missouri shore, particularly those living in the city of St. Louis. Additional complaint was made that accumulations of sewage sludge which had settled on the bed of the Chicago river and on the shore bottom of Lake Michigan would become dislodged and be added to the polluting material swept into the Mississippi valley.

In reply, the defendants claimed that it was no new thing for Chicago to turn sewage into the Mississippi valley, as "the greater portion of the sewage of the district had been for many years discharged into the Des Plaines and Illinois rivers" by the operation of the Bridgeport pumping plant which lifted the diluted sewage from the Chicago river into the Illinois and Michigan canal through which it flowed to the Illinois river at Lockport. The defendants further held that during the flow of 359 miles between Chicago and St. Louis the sewage material derived from the former city would have abundant opportunity to become disposed of by natural processes of purification, and further that by reason of the inflow of some 300,000 cubic feet per minute of Lake Michigan water, which would accompany the sewage, the resulting dilution would actually benefit rather than damage the character of the water in the Illinois river.

They further claimed that much sewage material was poured into the Mississippi and its tributaries by cities nearer to St. Louis, both in distance and in time of stream flow, than was Chicago, and that the complainant should look to such sources of pollution as explanatory of the alleged damage to its water supply. They also claimed that inasmuch as St. Louis sewered into the Mississippi river, that city was itself largely contributing to the nuisance of which complaint was made, at least so far as the inhabitants of the down-stream towns of Missouri were concerned.

They further claimed that the Mississippi water as furnished to the city of St. Louis before the opening of the Drainage Canal was unfit for municipal supply.

Many experts; engineers, chemists, bacteriologists and men of other callings, were summoned to appear in this case and their testimony fills eight large volumes of 1,000 pages each, a

mass of "record" second to none in the history of the Supreme Court of the United States.

It was proposed to ask one man to abstract this testimony and to disentangle the valuable scientific material it contains from the legal mesh in which it lies embedded, but it was quickly seen to be beyond the power of a single individual to properly accomplish such an undertaking and therefore the present "symposium" was substituted wherein the participants on either side can display their views and give freer and wider interpretation of their opinions than was possible under the restricting rules of the Court.

Although somewhat foreign to the present discussion, it may not be without interest to state that opposition to the Canal arose from, and still exists in, other quarters and for different reasons than those considered in the Drainage Canal case. It has been proposed "to limit by international treaty with Canada the flow of water from the lake into the Drainage Channel lest the lake levels be reduced to the detriment of the industrial water power at Niagara."

In a report dated April 24, 1895, the words appear: "In my opinion the abstraction of from 300,000 to 600,000 cubic feet per minute will permanently lower Michigan, Huron and Erie from three to eight inches; not more than eight nor less than three inches, corresponding to a reduction of from 240 to 700 tons in carrying capacity for large vessels of the lakes, and that it will take from three to four years for this full effect to be attained."

Experience has shown that the fear of permanently lowering the level of the Great Lakes through the abstraction of water by the Canal was not well founded. "The average level of Lake Michigan during the six years before the opening of the Drainage Channel was 1.52 inches above city datum. During the six years since that event the average level has been 4.28 inches above datum, or 2.76 inches higher than in the six-year period before the abstraction of the amount flowed through the Channel." (See Bul. Department Health, Chicago, May 19, 1906.)

Previous to and during the passage of the Drainage Canal Case through the Court thousands of analyses were made of the waters under observation and numerous experiments were

devised and executed with a view of clearing up the vexed question as to a probability of Chicago sewage polluting the water supply of St. Louis.

Two experiments among these stand out prominently, one on either side, and were of such a nature as to be widely commented upon in the public press. Acting for the plaintiff Dr. Ravold deposited in the Drainage Canal 107 barrels, containing 40 gallons each, of a culture of bacillus Prodigiosus and then sought for the germ in samples of water taken at sundry points along the river as far down as the St. Louis intake. Discussion of the results obtained will doubtless be had during this symposium. Upon the side of the defense Professors Jordon, Russell and Zeit made extended experiments dealing with the longevity of the typhoid bacillus in Illinois river water and in the dilute sewage of the Drainage Canal, and we are to expect here an exposition of their findings.

The main part of this noteworthy case lasted six years and thirty-two days. The preliminary court proceedings not being included in this time. Taking the testimony consumed 317 days, nearly 300 witnesses, including 35 experts, having been examined. The costs of the suit amounted to about $300,000.

In reading over the decision of the Court, which was in favor of Illinois and Chicago, one is reminded of the Scotch verdict, "Not proven." Missouri failed to fasten upon Chicago the responsibility for the alleged damage to the water flowing along her eastern shore and her case was further weakened by the fact that St. Louis, the chief complainant, did herself sewer into the river to the possible detriment of the towns lower down the stream.

The following extracts from the opinion of the Court may be of interest:

"We cannot but be struck by the consideration that if this suit had been brought fifty years ago it almost necessarily would have failed. There is no pretense that there is a nuisance of the simple kind that was known to the older common law. There is nothing that could be detected by the unassisted senses—no visable increase of filth, no new smell. On the contrary it is proved that the great volume of pure water from Lake Michigan which is mixed with the sewage at the start has improved the Illinois river in these respects to a

noticeable extent. Formerly it was sluggish and ill-smelling; now it is a comparatively clear stream, in which edible fish have returned. Its water is drunk by the fishermen, it is said, without evil results. The plaintiff's case depends upon an inference of the unseen."

"If this suit should succeed, many others would follow and the plaintiff not improbably would find itself a defendant to a bill by one or more of the States lower down upon the Mississippi."

"The evidence is very strong that it is necessary for St. Louis to take preventive measures, by filtration or otherwise, against the dangers of the plaintiff's own creation or from other sources than the Illinois. What will protect against one will protect against another. The presence of causes of infection from the plaintiff's action makes the case weaker in principle as well as harder to prove than one in which all came from a single source."

"Some stress was laid on the proposition that Chicago is not on the natural watershed of the Mississippi, because of a rise of a few feet between the Des Plaines and Chicago rivers. We perceive no reason for a distinction on this ground. The natural features relied upon are of the smallest; and if, under any circumstances, they could effect the case, it is enough to say that Illinois brought Chicago into the Mississippi water shed in pursuance not only of its own statutes, but also of the acts of Congress."

"What the future may develop, of course, we cannot tell; but our conclusion upon the present evidence is that the case proved falls so far below the allegations of the bill that it is not brought within the principles heretofore established in the cause."

"Bill dismissed without prejudice."

The foregoing rough historical sketch will serve as an introduction to the abstracts of testimony as prepared by the witnesses themselves, which abstracts, we hope, will be given in person.

Discussion.

Dr. W. P. Mason: After having monopolized so much of your time by what may be termed the historical introduction required in this case, it is fitting that I should give way to those who are ready to present in condensed form their views upon the scientific points raised during the proceedings.

With my own testimony I shall not risk wearying you by lengthy abstracts, for the reason that much of it dealt with matters of interest in this case only, and did not assume a form of general application. Some few points, however, may be worthy of mention:

With reference to the widely quoted bacillus Prodigiosus experiment, wherein 107 forty-gallon barrels of the culture, containing from 500 to 1,000 million bacilli Prodigiosus per c. c. were emptied into the Chicago Drainage Canal, and the germ afterwards sought for at the St. Louis intake; my opinion as given was, that in view of the enormous number of organisms introduced and the small number (5) found, the results of the experiment show a very considerable death rate among the germs employed in the test and that, by inference, at least as large a death rate of the bacilli of typhoid fever, which they represented, would occur if the latter were exposed to the same conditions.

No little time was devoted to a consideration of the longevity of the typhoid bacillus; contrasting its power of retaining life for months while in the human body, or while in moist soil, with the shorter duration of vitality when immersed in water; the latter period being measured by days.

Recognition was naturally had of the influence of the relative purity of the water under consideration upon the result and the tendency of the great density of germ life in polluted waters to inhibit a continuance of the typhoid organism. The view was held that in a relatively pure water its chance for life is greater than in one where it has to fight for existence amid saprophytic bacteria, and the question of the longevity of the germ in water was stated by saying that it dies out therein more or less quickly en masse, although some individual cells, being more resistent, may remain alive for a longer period.

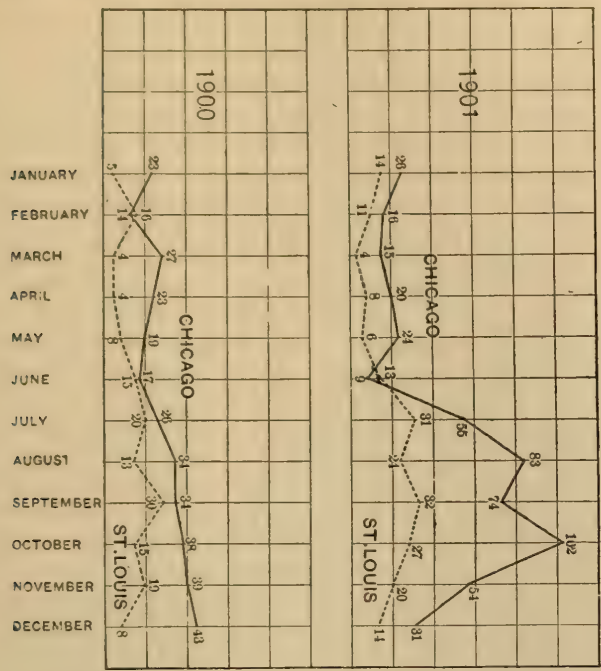
When contrasting the different results obtained while operat-

ing upon the experimental scale, using the glass containers common to the laboratory, and comparing them with those secured under conditions more nearly approaching what are found in nature, reference was made to the experiments conducted by the Massachusetts Board of Health (1902—page 259) touching upon the longevity of the bacillus coli communis. The vessel employed by the Board of Health was a large tank 12 feet deep. Under those circumstances the life of the germ in Merrimac River water was found limited to eleven days. By inference the typhoid bacillus would not have lasted so long. In other words, as we approach the conditions found in nature the opportunities for the destruction of the pathogenic organism seem to be greater than in those obtaining during a laboratory experiment.

Dilution, as a means of purification, was considered and the claim was advanced that although no destruction of organisms can be expected, yet the risk incurred by the man who consumes a pint of water at a draught is certainly diminished through dilution by reason of the fixed number of germs being distributed throughout an increased bulk of water. To the extent therefore that "purification" can be interpreted as a lessening of the degree of danger, to that extent dilution is equivalent to purification.

A point upon which stress was laid was the possibility of typhoid organisms accumulating in the mud of rivers by sedimenting from up stream sources, after a sort of "placer" fashion, and later becoming "scoured" out during times of flood to the damage of the populations below. As typhoid bacilli will live a long time in moist soil it is right to ask is similar vitality to be expected in the sludge of river bottoms? There are British statements made which answer this inquiry in the affirmative, but they do not appear to be supported by experimental evidence. On the other hand, the Massachusetts Board of Health experiment already quoted showed the absence of the Colon bacillus from the sediment collected at the bottom of the tank, the examination having been made after an interval of fifteen days.

Should accumulations of virulent germs collect upon river bottoms from up-stream sources and then later be washed out by floods, widespread disease would follow throughout the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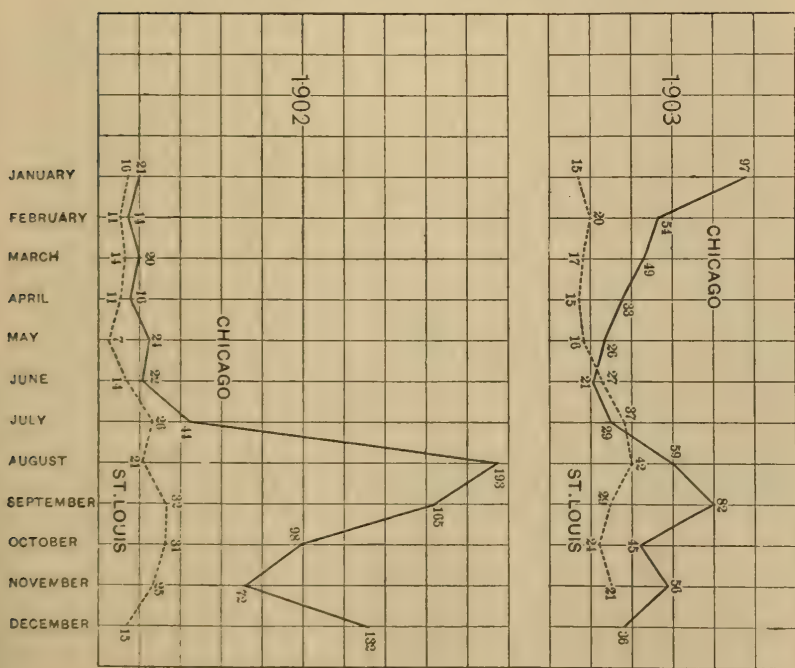
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sections below, yet upon inquiry we do not find recorded as close a relationship between floods and epidemic typhoid as we should reasonably expect under such assumption. With us in the Hudson Valley the high waters come in the Spring, but they are not followed by outbreaks of fever such as we should anticipate, were deposits of active germs scoured from the river bottom. It is easy to understand an increase of typhoid following the rise of a stream like the Tees, in northern England, but there the accumulations of filth which are swept seaward by the swollen river are not the result of sedimentation, but consist of night soil and other matters that have gathered upon the dry and rocky foreshores during periods of drought. Such a case is scarcely comparable with the gradual accumulation of river mud, for we know that typhoid germs will live for long periods of time in fecal deposits. In soil the water exists as "moisture" only, while in river sludge it is present in quantity, and opportunity is thereby given for the solution and adverse action of the toxins of antagonistic organisms. This view was, I believe, first advanced by Jordan, who backed it by experimental support, yet in stating it, the fact should not be forgotten that, Sedgwick in 1893 succeeded in growing typhoid bacilli in filtered sewage which contained no germ life of any kind, but was presumably rich in saprophytic toxins.

In an effort to show the connection, if any, between the prevalence of typhoid fever in the two cities of Chicago and St. Louis, the accompanying charts were constructed exhibiting the deaths from the disease by months for four years. The deaths in St. Louis are plotted one month in advance; thus the February numbers for St. Louis are made to correspond with the January readings for Chicago, in order to allow for the time consumed by the germ in making the journey by water, between the two cities, and for the further time required to develop a fatal result after the bacillus had been swallowed. To my mind there is a lack of parallelism between the curves as shown, nor is the case bettered by increasing the time allowance above noted to beyond one month, all of which does not point towards Chicago typhoid as causative of that found in St. Louis.

While on the witness stand the writer sought to lay stress

upon the importance of the element of "time" in the self-purification of water, and to call attention to the greater probability of St. Louis importing its typhoid from points of pollution nearer at hand than Chicago. In support of this view, data were offered which were later embodied in a paper before the New England Water Works Association, entitled: "Relation of Intensity of Typhoid Fever to Character of Water Carriage." (Vol. 19, page 412.) Time does not here permit of extended reference to that paper. Suffice it to say that in a mixed epidemic, which the writer had opportunity to study (*i. e.*, an epidemic caused by infected water from two sources) it was found that 27.8% of the typhoid cases were severe in type, where the disease was traced to a polluted stream, while 56.5% was severe when the fever was caused by water from contaminated wells. Again, in a report of 108 British epidemics we note that 75 of them, which were due to well waters, the typhoid death rate was 11.83% of the total cases, while in the remaining 33, which were caused by stream and reservoir infection, the rate was reduced to 9.85%. It would appear from this that support is given to the general proposition that the danger of illness and death will vary inversely as the length of time elapsing between the entrance of polluting material and the drinking of the water. Or, stated in other words, the typhoid germ under prolonged struggle for existence, will lose some of the vigor of its life and will become incapable of producing its normal amount of poison. Under such circumstances either no intoxication results or else a mild type of disease develops among those especially susceptible to invasion.

In conclusion let it be said that the amount of verbiage commonly employed in extracting from the witness a definite statement of his opinion is well illustrated in this case. Cannot the legal mind devise some method, by agreement of counsel or otherwise, whereby the testimony shall be relieved of all matters not truly essential. If so, the legal reports will no longer comment with such apparent pride upon "the great length of the record."

THE CHICAGO DRAINAGE CANAL—IN THE UNITED STATES SUPREME COURT.

By John W. Hill.

The suit of the State of Missouri against the State of Illinois and the Sanitary District of Chicago, in the United States Supreme Court, to restrain the City of Chicago from delivering its sewage into the Drainage Canal and finally into the head waters of the Illinois river (the sewage to be diluted with water from Lake Michigan at the present rate of 5,000 cubic feet per second, and ultimately at the rate of 10,000 cubic feet per second), was based upon the theory that the typhoid fever rates would be increased for the city of St. Louis and other cities in Missouri which draw their Public Water Supplies from the Mississippi river below the mouth of the Illinois river. Specifically it was contended that the typhoid fever bacillus coming with the Chicago sewage into the Illinois river would travel unimpaired in vitality from Chicago to St. Louis, and menace the health of the people of the latter city.

The history of the Chicago Drainage Canal appears to be as follows:

As early as 1871 by deepening the Illinois and Michigan Canal, a gravity flow amounting to 550 cubic feet per second was obtained from Lake Michigan. The amount of sewage pumped at Bridgeport into the Illinois and Michigan Canal, for the ten years prior to the opening of the Drainage Canal, has been estimated as 600 cubic feet per second,* or about equal to the flow of water from Lake Michigan into the South Branch of the Chicago river.

It thus appears that about 60 per cent. of the sewage of Chicago had been regularly discharged into the Illinois river at Joliet for twenty years before the legal contention upon the part of St. Louis and Missouri was raised, to the discharge of the sewage of the city of Chicago into the Drainage Canal.

At the present time it is assumed that 85 per cent. of all the sewage of Chicago is discharged into the Drainage Canal.

*"Sanitary Investigations of Illinois River and Tributaries," 1901, Page 114.

Thus the amount of sewage is but 25 per cent. greater than it was stated to have been prior to the construction of the Canal, at which time the dilution by lake water amounted to less than 600 cubic feet per second. Or, to put the matter in another light, the addition of 25 per cent. to the sewage discharge has been accompanied by an increase of 900 per cent. of the amount of diluting water drawn from the lake by reverse current in the main stem and South Branch of the Chicago river.

One view of the case would suggest that if 60 per cent. of the sewage of Chicago discharged into the Illinois river prior to Jan. 17, 1900, was not considered a menace to the water supply of St. Louis, or not sufficiently so to justify litigation, it is scarcely likely that the addition of 25 per cent. to the sewage discharged by Chicago into the Illinois river, accompanied by an increase of 900 per cent. in the volume of diluting water, could seriously impair the normal quality of the water flowing past the St. Louis intake—especially in view of the fact that the bulk of the water flowing in the channel of the Mississippi river in front of St. Louis, is derived from the water shed of the Missouri and Upper Mississippi rivers and their tributaries, and that relatively, the smallest portion is obtained from the water shed of the Illinois river, and the flow of water through the Drainage Canal which accompanies the discharge of the Chicago sewage.

Aside from any changes which may have taken place in the bacteriological and chemical constituents of the water of the Illinois river at Grafton and at other points between Grafton and Joilet, before and after the opening of the Drainage Canal, it would appear that a change of 25 per cent. in the amount of sewage discharged into the river, could of itself scarcely justify the contention of the city of St. Louis that its water supply was imperiled by the use of the Drainage Canal and Illinois river as a channel of discharge for this added amount of Chicago sewage—especially in view of the largely increased dilution with lake water.

The problem with reference to the water supply of the city of St. Louis seemed to depend not so much upon the amount of sewage contamination, which is much less than that of other rivers, like the Thames, Elbe, Weser, Schuylkill, Delaware and

the Ohio rivers, which are drawn upon for public water supply—as upon the amount of occult silt, clay, soil and silica carried in suspension, which is certainly not increased by the flow of sewage and lake water through the Drainage Canal.

I should regard the substantial removal of sewage from the water flowing past the St. Louis intake as not an exceptionally difficult proposition, but the large amount of suspended matter in the water—which is derived from other sources than the Illinois river—invests the purification and clarification of the St. Louis water with unusual interest. The writer did not understand that the legal controvery in any manner involved a consideration of the dissolved and suspended solids in the water of the Mississippi river at the intake of the St. Louis water works, excepting as this, or some of it, may be increased or harmfully changed in character by the flow of sewage and lake water from the Drainage Canal; and any statement in the testimony which he gave in the case with reference to the purification of the Mississippi river water at St. Louis, must be understood as touching only the natural and artificial sewage pollution of the water.

If the runoff of rainfall on the water shed of the Illinois river, including the sewage discharge of cities on this river and its tributaries through natural or artificial channels—excepting of course the flow of sewage and lake water through the Drainage Canal—was such as to furnish an entirely satisfactory water for dietetic purposes, it is possible that a distinct change in the quality of the water flowing in the Illinois river would be effected, by the discharge of sewage at the outlet of the Drainage Canal; but such is not the case, and it cannot be shown that prior to January, 1900, the water flowing in the Illinois river was naturally fit for drinking and other domestic uses, and could be rendered so only by some approved method of water purification. Regardless of whether the flow of sewage from Chicago made the water better or worse, it would not substantially change the condition of the water of the Illinois river with reference to this stream as a source of city water supply, because in its best condition the water would demand purification before it could be accepted for hygienic uses; and such methods as would naturally be resorted to in order to safely adapt the water to domestic use would doubtless be

applicable as well after the Canal was opened as they would be before.

In giving his testimony in behalf of the city of Chicago, the writer, from the data submitted by the Trustees of the Sanitary District, and other data, undertook to show:

1. That a careful examination of the physicial and hydrographical conditions of the Illinois river and its water shed, in their relation to the water sheds of the Missouri river and the Mississippi river above St. Louis, were such as to make the Drainage Canal a small factor in determining the quality of the St. Louis water supply.

2. That disregarding the technical data collected by Dr. Jordan and Prof. Palmer, and others, the conditions after the Drainage Canal was opened were better than they were before.

3. That the general deduction from the technical data appeared to show that the actual quality of the water from the Illinois river at Grafton was better after the Drainage Canal was opened than it was before—the improvement probably being due to dilution of the sewage by lake water.

4. That the typhoid fever conditions of St. Louis, and the quality of the public water supply before the opening of the Canal, were such as to require filtration of the Mississippi river water, or the adoption of another source of supply, and that such filters and operation as would properly meet the conditions before the opening of the Drainage Canal would be competent to meet them after the opening of the Canal.

The physical and hydrographical conditions of the water shed of the Illinois river, in its relation to the water sheds of the Missouri river and the Mississippi river above St. Louis, have been carefully studied from the data supplied by the Census of 1900, and the report of the Engineering Commission on New Water Supply for St. Louis, 1902, and various reports and compilations prepared for the Trustees of the Sanitary District. For the purpose of comparing the conditions with reference to probable pollution of the Mississippi water at St. Louis, by Chicago sewage, with other rivers which are drawn upon for public water supply, data was compiled for several rivers known to act as carriers of city sewage.

In the following table are given the drainage area, population and density of population per square mile of the drainage

basin of the Missouri river and its tributaries; of the Mississippi river above St. Louis, and its tributaries (not including the Illinois river); of the Illinois river and its tributaries; of the Delaware river above Trenton; of the Delaware river at its mouth; of the Schuylkill river above Philadelphia; of the Merrimac river; of the Elbe at Hamburg, and of the Thames above Teddington Weir, London:

RIVER BASINS AND POPULATIONS.
(U. S. Census 1900, excepting the Elbe and Thames.)

River Basin.	Area Square Miles.	Population	Population. per Square Mile
Missouri	520,086	5,120,607	9.84
Mississippi	171,698	8,409,676	49.00*
Illinois	32,081	3,433,845	107.00
Delaware, above Trenton	9,217	1,430,367	155.20
Delaware, incl. Schuylkill	14,067	3,864,927	262.10
Schuylkill, above Fairmount Dam	1,776	386,244	217.50
Merrimac	4,662	853,562	183.10
Elbe, Hamburg	55,000	3,665,810	80.73
Thames, above Teddington Weir	3,766	1,056,415	280.50†
Thames, above Oxford	1,222	205,000	169.00†

Considering the Schulykill as the present principal source of Water Supply to Philadelphia, the urban population only on its water shed above Fairmont Dam, by Census of 1900 is 84 per square mile, showing physical conditions apparently less favorable than for Hamburg.

The urban population per square mile on the water shed of the Illinois river by 1900 census, was 72.

The drainage areas of the Mississippi, Missouri and Illinois river basins are given somewhat differently in the report of the Commission on New Water Supply for St. Louis, 1902.

Combining the two reports—each of which is entitled to full credence—it is found that of the total water shed of the Mississippi at and above St. Louis, 75.26 per cent. is represented

*Above St. Louis and not including drainage basins of the Missouri and Illinois rivers.
†Reported, 1893.

by the Missouri river; 20.34 per cent. by the Mississippi river (not including the Illinois river); and 4.40 per cent. by the Illinois river.

According to a report of the United States Engineers for October, 1891, the natural stream flow of the Illinois river at Kampsville (above Grafton) is given as 1,000 cubic feet per second. Presumably this is the least guaged stream flow for the year, and is used for the purpose of comparison with the probable flow from the Missouri and Mississippi water sheds.

Assuming the same rainfall and runoff for each of the river basins (Missouri, Mississippi and Illinois), and adding to the least stream flow of the Illinois river the diluting water drawn from Lake Michigan—viz., 300,000 cubic feet per minute, or 5,000 cubic feet per second—then of the total flow of the Mississippi river at St. Louis 21.64 per cent. is obtained from the Illinois river. Of the total flow of the Illinois river, at period of least natural stream flow, 7 per cent. is due the Chicago sewage; or of the total stream flow of the Mississippi river at St. Louis 1.5 per cent. is chargeable as Chicago sewage.

Prior to the opening of the Drainage Canal, of the flow of the Illinois river at Kampsville (taken as a minimum of 1,000 cubic feet per second), the sewage flow from the old Bridgeport Station was equal to 31.8 per cent. of the whole volume of flow, or 1.40 per cent. of the flow in the Mississippi river at the St. Louis intake.

It would thus appear that the opening and use of the Drainage Canal as a sewage outfall, with the addition of 5,000 cubic feet per second of water from Lake Michigan, had slight effect on the relation of the discharge at Grafton of the Illinois river, to the flow of the Mississippi river at the St. Louis intake.

In stating the percentages of low stream flow at the St. Louis intake chargeable to Chicago sewage, before and after the opening of the Drainage Canal, it must be considered that of city sewage about one part per million is solid matter; the bulk of which, if not all, in the Chicago sewage, during a trip of 357 miles from Chicago to St. Louis, in a channel of low slope like the Illinois river, would be reduced by chemical processes and the action of bacteria, into innocuous compounds, or be deposited in the quiet reaches of the river above the

numerous dams constructed by the U. S. Government for slack water navigation; and of the Chicago sewage proper it is probable that no part of the suspended matter ever reaches St. Louis during the dangerous period of low natural stream flow in the Illinois river.

Considering the sewage pollution of a river drawn on as a source of water supply by a city, and admitting that by processes of oxidation and sedimentation there is a self-purification of sewage pollution going on in streams, and that this self-purification is measured by the time or distance required for the water to flow from the point of pollution to the point of water intake, it might be assumed that the pollution of a given water supply will be as great by the sewage flowing into the stream from a small community nearby, as that from a larger community more distant. To put the proposition in more concise form, ten thousand people ten miles up stream from a given point of intake, would probably be as much of a menace to the water supply of a given city as would one hundred thousand people 100 miles up stream from the same point of intake. While the amount of sewage in the latter case would be ten times that of the former, the time for the sewage polluted water to flow to the point of intake would be ten times as great, and the degree of oxidation and sedimentation should be ten times as much; and the probabilities are that the pollution of the stream would be quite as great from the small community nearby as from the larger community a hundred miles away.

This suggests a method of comparing different drainage areas where the channels of discharge are drawn upon for public water supply, with reference to a particular point of intake. Taking the populations of the larger cities and towns upon the drainage basin, and the distance of each above the point of intake, the aggregate quotient of the respective populations, divided by the corresponding distances above the point of intake, furnishes a factor by which different drainage areas may be compared.

Considering any drainage basin as a source of water supply, three factors appear to enter into the discussion:

1. The area of the drainage ground.
2. The population living upon the drainage ground.

3. The distance of the center of population above a particular point of intake.

The larger the water shed, other things being equal, the greater would be the volume of water flowing into the drainage channel; the smaller the population living upon the water shed, the smaller will be the sewage pollution of the run-off of rainfall; and the greater the distance of center of population from a particular point of intake, the less would be the influence of such sewage pollution on the quality of the water at the point of intake.

Another important factor of course enters into an investigation of this kind; thus, the general slope of the drainage basin to the channel of discharge, and the slope of the channel itself, are usually of the same character. Steep slopes of drainage grounds are usually accompanied by steep slopes of delivery channel, and flat slopes of drainage grounds are accompanied by flat slopes of the streams which carry the water away. If the several drainage areas are of the same general slope, no attention need be paid to the slope, but in comparing drainage areas of different slopes some regard should be had for "slope," because this determines the time for a sewage polluted water to travel from the point of entrance of sewage to the point of water intake.

So far as the three principal rivers uniting above St. Louis are concerned, the difference of slope of drainage grounds and channels of discharge are not significant, and are neglected in this investigation.

Considering the self-purification of sewage polluted streams with reference to a particular point of intake, it is obvious that the distance between the point of sewage pollution and the point of water intake, and the length of time required for the water to flow from the first station to the last, would determine the relative degree of self-purification. Assuming a constant velocity in a river channel, a flow of 200 miles should produce roughly twice the degree of self-purification that would occur from a flow of 100 miles. Therefore, the farther the center of polluting population is removed from a particular point of water intake, and the greater the length of time for sewage to travel from one point to the other, the less would be the danger of injury to users of the water, by reason

of sewage pollution on the water shed from which the water supply is derived.

Adopting this suggestion as a rough means of comparing different drainage basins for probable sewage pollution, it has occurred to the writer that a factor could be obtained showing the relative sewage pollution of sources of water supply at given points of intake, in the following manner:

The population of each urban center of four thousand or more, on each of two or more water sheds, is divided by the distance of such center from the point of water works intake, measured along the stream. The total urban populations, divided by the sum of the quotients obtained, would fix the center of gravity, or mean center of population, with reference to the sewage pollution of the stream above the point of intake.

The quotient thus obtained would furnish a factor by which such stream, and its drainage basin and population can be compared with some other stream, drainage basin and population; treated in like manner, the factors—i. e., the quotients of the urban population, divided by the distance from given point of intake—are comparable with each other; and that factor which has the lowest numerical value, all things equal, would indicate the drainage basin most favorable as a source of Public Water Supply, with reference solely of course to sewage pollution from urban centers.

Proceeding upon the theory that the polluting influence of population on the river water will vary directly with the population in any center or zone, and inversely as the distance of such center or zone from the point of intake, the following results are obtained for three cities:

Hamburg, with the Elbe river as the source of water supply.

Philadelphia, with the Schulykill river as the source of water supply.

St. Louis, with the Illinois river as a supposed source of water supply.

Hamburg.

The total urban population above Hamburg on the water shed of the Elbe river and its tributaries, is 3,665,810, or on a drainage area of about 55,000 square miles there is 66.6 population per square mile. Dividing the population of each of the principal cities considered, by the distance from Ham-

burg, we obtain the center of population as 253 miles from Hamburg. That is to say—if the whole urban population was assembled at a point 253 miles up stream from Hamburg, the polluting effect on the Elbe, so far as the point of intake is concerned, would be the same. The population per square mile, divided by the center of population, furnishes the factor for purposes of comparison, which for Hamburg is $\frac{67}{253} = 0.265$.

PHILADELPHIA.

Total urban population of the drainage area of the Schuylkill river above Fairmount dam, 160,732; area of water shed 1,915 square miles; population per square mile 83.93. The center of population calculating in the same manner as for Hamburg is 28.4 miles up stream from Fairmount dam and the ratio of urban population per square mile to center of population becomes 2.90; or the apparent possible sewage polluting conditions of the Schuylkill at Philadelphia is ten times that of the Elbe at Hamburg.

(This must not be accepted as literally true, because the 26 slack water dams in the Schuylkill above tide water form as many settling basins, in which at ordinary stages of the river, a large amount of suspended matter is deposited, and the real condition of the Schuylkill is much better than this showing would make it, although worse than that of Hamburg and much inferior to the conditions at St. Louis.)

ST. LOUIS.

Assuming that the Illinois river was the sole source of water supply: The total urban population on the water shed of the Illinois river is 2,082,836; the total drainage area 32,081 square miles; and the population per square mile, 65. The center of population from the St. Louis intake is calculated as 291.54 miles, and the ratio of population per square mile to center of population 0.223, or roughly, about the same as for Hamburg.

Considering, however, a mixture of Illinois, Mississippi and Missouri waters, the natural conditions at St. Louis would be much improved. In the Report of the Engineer Commission on New Water Supply for St. Louis, 1902, the urban population on the water shed of the Upper Mississippi and tributaries, not including the Illinois river, is given as 621, 327; the drainage area, from U. S. Census 1900, as 171,698 square miles; and urban population per square mile, 3.60. The calculated

center of population is 469 miles above St. Louis, and ratio of population per square mile to distance of center of population, 0.0077.

The St. Louis Water Supply report gives the urban population on the Missouri water shed as 713,254, the drainage area, by 1900 Census, is given as 520,086 square miles, and urban population per square mile 1.37. The calculated center of population is 575 miles up stream from the St. Louis intake, and ratio of population per square mile to distance from intake to center of population, 0.0024.

Assuming further that of the total natural flow in the Mississippi river at St. Louis, 75 per cent. comes from the Missouri river, 20.5 per cent. from the Upper Mississippi, and 4.5 per cent. from the Illinois drainage basins, then the resulting factor, for comparison with Hamburg and Philadelphia, becomes 0.0134.

Arranging these factors for comparison:

Hamburg	0.265
Philadelphia	2.900
St. Louis	0.0134

They show that the natural conditions, population per square mile, center of population above intake, and stream flow, overwhelmingly favor the latter mentioned city; and if it is possible—as experience has shown—to successfully filter the water of the Elbe at Hamburg, and the Schuylkill river at Philadelphia, it should be less difficult, so far as sewage pollution is concerned, to filter the water of the Mississippi river at St. Louis.

In making this statement the silt bearing condition of the Missouri river is not lost sight of, but this, as Kipling would say, is another story, and had no place in the legal controversy over the right of Chicago to use the Drainage Canal as a channel of sewage discharge.

The volume of discharge of the Illinois river at Grafton, since the Drainage Canal was opened, is larger by the 300,000 cubic feet per minute of lake water plus the additional flow of Chicago sewage.

Disregarding the natural flow of the river due to the run-off from the rainfall on the water shed, prior to the opening of the Canal the flow of Chicago sewage at Bridgeport amounted to about 180,000,000 gallons per day, and the dilution often prac-

tically nil, because the total pumpage from the South Branch of the Chicago river was too low to produce a reverse flow of water from the lake, sufficient to dilute the sewage flowing in the South branch, and the total discharge by the pumps into the Canal flowing to the headwaters of the river was plain sewage.

Since the opening of the Canal, while the volume flow of sewage has been largely increased, it has been accompanied by a larger volume of lake water, having the effect to dilute the sewage and render the mixture less noxious than the previous smaller volume of undiluted sewage pumped into the Illinois and Michigan Canal at Bridgeport.

From the foregoing discussion can be drawn the conclusion that long prior to the opening of the Drainage Canal, the condition of the Illinois river was not such as to make it a fit source of public water supply; that as a natural source it was better than some other rivers which have long been used as public water sources; that it has not deteriorated since the opening of the Canal; and that by reason of the small relative flow of the Illinois river, when compared with the Mississippi and Missouri rivers, it never has had a marked influence on the St. Louis Water Supply.

Considering the flat slope, numerous swells, or lakes so-called, in the Illinois river, and the five dams constructed below Peoria, by the U. S. Government, for slack water navigation, it is very doubtful if Chicago sewage as such ever reaches Grafton at the mouth of the stream.

Considering the changes in the chemical and bacteriological conditions of the Illinois river at Grafton, by comparison of notes taken for the months of June, July, August and September of 1899, and the same months for 1900, the following changes appear to be sustained:

The bacterial content of the water has been increased by	73	per cent.
The suspended matter has been increased by	16	"
Total solids reduced by	7	"
Oxygen consumed, reduced by	23	"
Nitrites reduced by	66	"
Nitrates increased by	22	"
Chlorine increased by	3	"

While the bacterial content, suspended solids and chlorine have been increased, the reduction of total solids, oxygen consumed and nitrites, taken together with the increase of nitrates, appear to indicate a higher degree of sewage reduction or dilution, and self-purification of the stream after the opening of the Drainage Canal.

For another purpose, and prior to his investigation of the Drainage Canal case,* the writer had a series of tests made by Mr. W. R. Copeland (at that time bacteriologist of the Bureau of Filtration, Philadelphia), to determine the probable longevity of the typhoid bacillus and bacillus Coli Communis, in sterilized raw Schuylkill and Delaware waters, while carrying the normal and increased amounts of chlorine; from which was obtained the information that without regard to the chlorine content, the life of the typhoid bacillus was limited to 8 days, and B. Coli Communis to 14 days; and if the bacillus of typhoid fever lives no longer in the raw water, containing hardier species for which the water is a normal habitat, then it would seem to be impossible to charge to the Chicago sewage, typhoid fever organisms which might exist in the water of the Mississippi river at St. Louis. The time for water to travel from Chicago to St. Louis ranges from 10 to 20 days, depending upon the natural stage of the river—the longer time being coincident with low natural stream flow; that is to say—the longer time of stream flow occurs when the conditions with regard to Chicago sewage would be the worst, and when the possibility of the typhoid fever bacillus, or even bacillus Coli Cummunis, traveling from Chicago to St. Louis, would be very remote indeed.

As interesting data on the life of the typhoid fever bacillus in sterilized river waters, the writer includes the tables showing Mr. Copeland's work, which furnishes information on several points:

1. That the chlorine content of the water, ranging from normal to an addition of 300 parts per million, had no appreciable influence on the life of the typhoid organism.

2. The period of disappearance of the typhoid organism in sterilized raw water, ranged from 5 to 8 days.

*October, 1901.

Table showing results of Experiments to determine the Longerity of B. typhi abdominalis in Sterilized Raw Water of Schuylkill and Delaware Rivers under Various Conditions of Chlorine content.

Spring Garden Testing Station, – Philadelphia, Pa.

Numbers given are Bacteria per Cubic Centimeter.

Number of Test	Date of Inoculation of Test Flasks.	Average Temperature During Experiment: Test Flasks	Average Temperature During Experiment: Schuylkill Water at Entrance to Bldg.	Est. Organic Matter introduced in 6 Test Flasks in Parts per Mill.	Kind of Water	Chlorine added to Water in Parts per million	Numbers of B. Typhi abdominalis in Test Flasks after Incubation at given Temperatures for Periods in days as follows:- 0	1	2	3	5	8	12	14	22	Temperature of Incubation of Plates	Kind of Medium	Number of Days of Incubation
4	Oct. 7th 1901	73°F.	64°F	0.25	Schuylkill River	0	130	120	27	7	0					39°C	Lactose Agar	1
				"	Delaware River	0	150	100	12	0	0							
				"	"	25	150	140	100	55	0							
				"	"	50	150	65	12	0	0							
				"	"	75	140	80	6	1	0							
				"	"	100	150	60	11	1	0							
				"	"	200	160	75	6	1	0							
				"	"	300	130	80	26	4	0							
5	Oct. 16th 1901	63°F.	62°F.	50.0	Schuylkill River	0	110000	43000	25000	4200	1000	3	—	0		39°C	Lactose Agar	1
				"	Delaware River	0	110000	38000	25000	6200	1200	1	0	0				
				"	"	25	110000	41000	28000	8100	1800	1	0	0				
				"	"	50	80000	34000	22000	4900	1000	1	—	0				
				"	"	75	85000	35000	26000	7500	1700	0	—	0				
				"	"	100	100000	36000	24000	9800	2000	3	—	0				
				"	"	200	74000	63000	27000	12000	2500	4	—	0				
				"	"	300	62000	34000	23000	2200	600	0	—	0				

Table Showing Results of Experiments to Determine the Longerity of B. Coli Communis in Sterilized Raw River Water of Schuylkill and Delaware River under Various Conditions of Chlorine Content.

Spring Garden Testing Station, Phila. Pa.

Numbers given are Bacteria per Cubic Centimeter.

Number of Test.	Date of Inoculation of Test Flasks.	Average Temperature During Experiment: Test Flasks	Average Temperature During Experiment: Schuylkill Water at Entrance to Bldg	Estimated Organic Matter introduced into Test Flasks in Parts per Million	Kind of Water	Chlorine added to Water in Parts per million	Numbers of B. Coli Communis in Test Flasks after Incubating at given Temperatures for Periods in Days as follows:- 0	1	2	3	5	8	12	14	22	Temperature of Incubation of Plates	Kind of Medium	Number of Days of Incubation
4	Oct. 7th 1901	73°F.	64°F.	0.25	Schuylkill River	0	180	230	1700	to Thick	To count	= contaminated				39°C	Lactose Agar	1
				"	Delaware River	0	180	140	61	49	—	15						
				"	"	25	180	140	16	2	—	0						
				"	"	50	160	100	9	4	—	1						
				"	"	75	170	120	13	5	—	2						
				"	"	100	160	130	22	6	—	2						
				"	"	200	200	140	18	3	—	1						
				"	"	300	190	180	33	7	—	2						
5	Oct 16th 1901	63°F	62°F	50.0	Schuylkill River	0	41000	18000	2500	2000	1400	800	400	400		39°C	Lactose Agar	
				"	Delaware River	0	35000	13000	2200	350	70	30	11	8				
				"	"	25	61000	16000	4300	1200	240	120	63	44				
				"	"	50	35000	15000	4300	1400	650	110	52	37				
				"	"	75	46000	9200	2100	750	300	110	17	19				
				"	"	100	45000	17000	6200	650	300	43	17	8				
				"	"	200	35000	12000	1600	700	80	35	8	2				
				"	"	300	42000	13000	4300	1400	550	100	55	34				

3. That the colon bacillus had a longer existence, ranging from 8 to 14 days, and was apparently immune to the chlorine in the water.

4. Optimum conditions were chosen to secure the longest possible life—conditions which could not obtain in a river carrying all kinds of strong organisms of fermentation, and which would probably render the life of the typhoid bacillus of short duration in the raw water.

One of the experts for the complainant, in his evidence called attention to the storage and settling reservoirs of Covington, Ky., having about 30 days' capacity, which in his opinion had failed to protect the people using the water, from typhoid fever. Being familiar with the reservoirs and conditions at Covington, the writer deems it advisable to correct the impression which this loose statement is calculated to leave.

Covington is really a suburb of Cincinnati, although lying in another State, with the Ohio river between. A very large proportion of the people visit Cincinnati daily for business, educational, social or shopping purposes. If the city had the purest water on earth, it would afford but little protection from typhoid fever to many of the people who are daily migrating to Cincinnati. As a matter of fact, however, the typhoid fever rates of Covington are lower than for Cincinnati, notwithstanding they both draw their supply from the Ohio river.

DEATHS FROM TYPHOID FEVER PER 100,000 OF POPULATION LIVING.

Source of water supply for both cities, Ohio river.

Cincinnati, limited sedimentation, not exceeding two days, on continuous plan.

Covington, 30 days' sedimentation, on continuous plan.

Years.	Cincinnati.	Covington.
1890	67	43
1891	62	48
1892	40	44
1893	44	31
1894	54	50
1895	39	32
1896	52	39
1897	32	..*
1898	33	..*
1899	37	..*
1900	37	28
1901	55	..*
1902	62	7
1903	45	4
Average	47.07	32.60

And this constantly lower rate the writer has long since ascribed to the long sedimentation of the Ohio river water in the Covington reservoirs before it goes to the users, with a corresponding beneficial effect on such of the people as do not at all, or very infrequently, cross the Ohio river.

Considerable thought was given to the filtration of the St. Louis water, as a safeguard to the dangers which surrounded it long prior to the opening of the Drainage Canal; and as evidence of water purification by Plain Sand Filtration, the data obtained from the operation of the Philadelphia filters were freely drawn upon. These showed as a practical demonstration that the typhoid fever rates in the districts supplied exclusively with filtered water were from 80 to 85 per cent. lower than adjoining districts supplied with unfiltered water; that the bacterial reduction averaged for a year on the raw Schuylkill water, ranged from 99 to 99.66 per cent., as follows:

Lower Roxborough	99.66†
Upper Roxborough	98.81
Belmont	99.27

*Unable to obtain data for blanks at time of preparing table.

†Lower Roxborough Station furnished with pre-filt rs working at the rate of 55 million gallons per acre per day.

with turbidity reductions averaged for a year on the raw water, ranging from 89 to 96 per cent., as follows:

Lower Roxborough	96.02*
Upper Roxborough	89.78
Belmont	89.20

and that the colon bacillus was rarely found in the filtered water from any individual filter, and not at all in the water samples taken from the clear water basins.

It is doubtful if cities will seriously consider the subject of sanitary sewage disposal until after we have exhausted our resources in the purification of polluted streams, etc. If filtration actually reduces the typhoid fever rates by 80 per cent. or more, and only the sentimental objection to the use of a previously sewage polluted water remains, it is even more doubtful if cities can be induced to expend large sums for sewage disposal, excepting it is conclusively shown that this will render easier or cheaper the cost of filtration. The people want results, and are not much concerned as to methods. The result of water purification will be a marked reduction of the typhoid fever rates, and this accomplished, the sentimental objection to the water source will have little practical weight with the general public.

With reference to water sources drawn on for city supply, I think if the pollution by artificial means is such as to render the water, when analyzed by our best known methods, no worse than it is by pollution from the natural and uncontrollable means, no practical objection to such artificial pollution can be offered. There is always, however, the sentimental objection that such water has received artificial sewage pollution—but it is a question how far cities are willing to expend large sums of money simply to allay a sentiment.

If fires caused no loss of life and property, and no danger or discomfort, we would have less elaborate fire departments, or none at all. If travel on mud roads was not accompanied by large wear and tear of horseflesh, delays and discomforts, we would have no paved streets. If houses and streets could be as well lighted with tallow candles, with no more expense and labor, we would have no gas or electric lights. Every great improvement in municipal works is the result of the necessities of the people, and excepting the things that appeal to the eye, few such improvements can be credited to sentiment.

*Lower Roxborough Station furnished with pre-filters working at the rate of 55 million gallons daily.

THE SELF-PURIFICATION OF THE MISSISSIPPI RIVER DURING THE LATTER PART OF ITS COURSE.

By Robert Spurr Weston.

The writer's testimony in the Chicago Drainage Canal case bore upon one important point, and in view of the great volume of testimony given, it seems best to give only a very brief exposition of this point and indicate its bearing upon the general case.

There are two extreme conceptions of stream purification:

The first, that a stream purifies itself every dozen miles or so;

The second, that no stream is long enough to do so.

Somewhere between these extremes lies the truth. If any river would furnish valuable evidence bearing upon this point, the Mississippi would be that river, because of its location, character, drainage areas, adjacent population and conditions of flow.

While the population of the Mississippi River basin is enormous, including as it does, the cities of Chicago, Minneapolis, St. Paul, St. Louis, Louisville, Cincinnati, Pittsburg, Allegheny, Memphis, New Orleans, and many others, the population is so located and the topography is such that most of the sewage of this population is discharged into a river a thousand miles or more above its mouth. While the population is enormous, it does not seem to be the most important factor which affects the character of the stream at New Orleans.

A short description of the watershed may be of interest. It has an area of about 1,240,000 square miles, and includes eleven whole States and Territories, besides parts of twenty othere; also part of Canada. There is great diversity of soil, climate and population. This is very easy to comprehend when one considers that within the Mississippi Basin are the slopes of the Alleghanies and the Rockies; the lakes of New York, Minnesota and the far West; the limestone country of Ken-

tucky and Tennessee, and the black bottoms of the Dakotas; the fertile plains of the Central West and Colorado and the swamp lands of the Central Valley itself.

Six natural basins combine to form the Mississippi Basin. Of these the largest is the Missouri, with 43 per cent. of the area. The rainfall in the various basins varies greatly, from 51.5 inches per annum in the central valley, to 19.4 inches in the Missouri basin, so that while the area of the Missouri basin is largest, it occupies third place in the table of stream discharges, the first place being given to the Ohio basin, which is second both in area and rainfall.

For the last thousand miles or so of its course the Mississippi River flows through a delta, for the most part of the way between leveed banks. Whereas the land is highest at the river bank, it follows that the natural drainage is away from the river. The above does not take into account the four cities which discharge sewage into the river within 600 miles of New Orleans. These cities are Baton Rouge, Natchez, Alexandria and Vicksburg. Their populations and distances from New Orleans are shown in the following table:

City.	Population.	Distance from New Orleans.
Baton Rouge	11,269	131 miles
Natchez	12,210	265 miles
Alexandria	5,648	300 miles
Vicksburg	14,834	554 miles

Whereas the discharge of the Mississippi River at New Orleans varies from about 191,000 to 1,353,000 cu. ft. per second, it follows that the dilution of the sewage from the cities immediately above New Orleans is enormous and would probably of itself obliterate any effect of the same upon the character of the water at New Orleans, as indicated by chemical and bacteriological analysis. The sewerage of the eight or nine million people living above Memphis is not so highly diluted.

There exist, then, admirable conditions for the study of the problem of the self-purification of streams. Here is a long, large river receiving a large amount of sewage along its upper course and an insignificantly small amount where it flows through its lower course, and where the natural slope of the

land away from the river prevents any fresh accessions of sewage. What, then, are the effects of the urban population upon the water at New Orleans?

Chemical analysis show that the "nitrites" are high,—probably because of decomposing organic matter which has been absorbed from the swamp water by the suspended clay of the stream and is being rapidly oxidized by the normal bacteria of the water. Apart from the suspended matter, the water is potable, so far as chemical analysis can establish this fact.

If the population affected the character of the river water at New Orleans, one would expect to find Bacillus coli more or less frequently, just as it is found in the Ohio, the Tennessee or the Mississippi River. Tests were made at the Laboratory of the Sewerage and Water Board of New Orleans from December, 1900, to April, 1901. Six tests a week were made in December. The number of tests, however, was gradually decreased in 1901, until April, when they were discontinued.

During this time the Bacillus coli,—the characteristic organism of the human intestine, and therefore indicative of sewage, —was found in 1 c. c. portions three times during the first week of December, 1900. Later, in February and March, it was absent in 1 c. c. portions. The presence of the bacillus in December can be explained by the fact that the tests were made immediately following a rise in the river. Previous to this rise the banks of the river between the water level and the levee, on what is known as the batture, were occupied by numerous, squatter house boatmen. These boats had been resting upon the batture since the previous spring. The intake of the water purification station, where the experiments were made, was immediately below this colony. It is easy to see, therefore, how the first rise of the river after the period of low water would scour the batture in the vicinity of these houseboats, and therefore the presence of Bacillus coli in the water of the river in the immediate vicinity of the houseboats might be explained.

The bacteria isolated from the water of the Mississippi River at New Orleans were of few kinds. They were hardy liquifiers, motile and non-aerogeneous. It is the writer's opinion that the population of the Upper Mississippi River and its branches has not affected the character of the Mississippi River at New

Orleans from a sanitary standpoint. It is also believed that the occasional evidences of pollution which exist may be attributed to accidental conditions. It seems probable that the normal bacteria in the river have crowded out the exotic bacteria of human origin until little or no bacteriological evidence of sewage pollution exists.

TESTIMONY BY PROFESSOR T. J. BURRILL,

OF THE UNIVERSITY OF ILLINOIS.

Circumstances beyond my reach have made it impossible to prepare the promised abstract from my testimony in the case of The State of Missouri vs. The State of Illinois and the Sanitary District of Chicago. I regret this very much, but can now only say in the briefest manner possible that I did give the chief results of the examination made by me of the drainage waters from Chicago to St. Louis, during the period from June 1, 1899, to October 15, 1900—before and after the opening of the Sanitary Canal. Besides the direct observations made upon the streams there were bacteriological analyses made in my laboratory of 2,800 samples of water, from 26 to 32 collecting stations, located on the direct course of the stream and near the mouths of the main tributaries. From these samples about 30,000 cultures and entries of results were made, for the purpose of determining the number of bacteria and the occurrence of representatives of the group of organisms usually included under the name of *Bacillus coli communis*.

The general results clearly showed that some 3,000,000 to 10,000,000 bacteria per cubic centimeter existing in the head waters near Chicago became gradually reduced until at Averyville (North Peoria) 159 miles distant, there were an average of about 1,000 to 5,000—something like the usual content of the common river waters of the region. This reduction is not mainly due to dilution with clearer water, because the tributaries at their mouths are practically similar to the main stream at the junction, and in this level country there is comparatively little spring water which finds its way directly into the current.

After excessive pollution again at Peoria and Pekin, where there are the greatest distilleries and glucose factories in the world, and where the refuse from these and from hundreds of large cattle sheds as well as the sewage of nearly 100,000 people enters the river, the bacterial count rises again to the millions, while at the mouth of the Illinois river, another 159 miles distant, the number of bacteria is again nearly as low as

at Averyville, and quite as small as in the Mississippi above the junction. In this part of the stream there are stretches of 25 to 50 miles where the volume of water is scarcely increased at all, but in which the diminution of bacteria takes place as before stated.

For some reason not very well understood the bacteria proved to be commonly greater in number in the water of the Missouri river than in that of the Mississippi before their union.

It was very evident that during the flow of the water there took place a survival of the fittest in regard to the specific kinds of bacteria, for the number of species diminished much more rapidly than did the number of individuals. In other words, 100 colonies upon a plate were much more diverse in kind from near the sources of pollution than was the case from water 50 or more miles away from such contamination.

The cultures made on the spot averaged lower from the head waters of the stream, and higher from stations showing least contamination than were found in the samples transmitted in ice to the laboratory after an interval of 20 to 30 hours.

The colon bacillus proved to be more or less present in the water at every station. That is, these organisms were always found in the most polluted waters and *sometimes found* in those in which general bacterial count was lowest. The percentage of positive tests, using in each case a centimeter of water, varied from 100 to about 25 and followed closely the general count, though the percentage was commonly higher at the mouth of the Illinois than at Averyville.

From all these studies it seemed certain that the stream rapidly and abundantly purifies itself, and that after taking all other causes into account the purifying process must be very largely ascribed to the activity of the living agents of decomposition. The bacteria themselves are the greatest agents of purification, aided much and also destroyed by other living creatures. These studies, however, seemed to show that to a slight extent the water at Averyville and at the mouth of the Illinois contained more bacteria after than before the inflow of the lake water. That is, the fermentation processes seemed to be pushed somewhat further down the stream by

the greater volume of cold water. But it seemed clearly certain that no charge could be substantiated that the water at the St. Louis pumping works carried pathogenic bacteria derived from the pollutions at Chicago.

Discussion by Professor Gardner S. Williams.

Mr. Chairman and Gentlemen:

I was on the other side, the St. Louis side of this question. One of the very interesting features to me of the whole case was the absence from it in the legal part, of any one having experience in litigation of a similar nature; and whatever bearing that may or may not have had upon the outcome, it perhaps is right to remember that the cause was to a very large extent tried under the direction of attorneys who were not familiar with the history or procedure in those approaching this in characteristics.

There are two rather interesting legal phases it may be well for me to mention. First: The contention of the State of Missouri that Chicago had cut through a natural barrier and diverted sewage out of its natural course into every St. Louis homestead, was held by the court apparently to be of no consequence by reason of the fact that that procedure had been going on for years under the authority of the United States Government, which had provided for the construction of the Illinois and Michigan Canal. And, second, a point, which was not emphasized so far as I am aware, in the finding of the court, nor do I recall that it was touched upon to any great extent in the arguments; but nevertheless was, I think, an important factor. In looking over the decisions of courts in various matters, it is extremely rare that you find a case where a person who has permitted a construction to be carried on and a large expenditure of money to be made without protest, is at the completion of the work allowed to step in and render its effects nugatory; in other words, when St. Louis failed to protest during the construction of the Canal, waited until it was all finished, till the entire expenditure had been made, and only then applied for an injuction to prevent Chicago from using it, that city threw away one of the very strong vantage grounds that it might have had in the suit. On the other hand, it might have been difficult for St. Louis to have established a case at the time that the Chicago Drainage Canal was under construction. It appears to have been rather difficult for her to establish it at the time that it was completed; and I venture to say it would have been vastly more difficult had it been at-

tempted five years, or ten years, earlier. I think we are safe in saying that there would have been absolutely no hope of securing an injuction against the construction of the Chicago Drainage Canal at the time it was first recommended, or at the time that work upon it was begun. It is entirely probable that ten years from now it might be possible to prevent the construction of a similar work. It is quite probable that such construction might be prevented now; but I doubt very much if it will ever be possible to legally restrain Chicago from delivering sewage through that canal, whatever the effects upon St. Louis may be.

The question as to whether the Mississippi River water was previously a fit water to drink, or not, has very little if any bearing upon the merits of this case. If Chicago by the discharge of sewage into it through any route made that water any worse than it was before, certainly there was a damage, and it was only a question of establishing the amount. That phase of the problem it hardly seems to me was a very strong argument in favor of Chicago's case. Either the Chicago Drainage Canal did no damage or it did some damage. If it did none, then of course the case fell. If it did any damage, even though the water of the Mississippi River at the Chain of Rocks was not an ideal water, if it was any worse by reason of the addition thereto of the dilute sewage of Chicago, then St. Louis would have been entitled to damage had she sought it, were there not acts of substantial estoppel.

About a year ago in discussing with a very eminent engineer, who passed away from this life last week, the question of the possibility of disagreement between two engineers who were to deal with an important problem, he said to me. "If two engineers meet to consider a problem and are unable to agree upon a general method of solution, either one of two things must be the fact: that there is not sufficient evidence, that they have not sufficient knowledge, sufficient data upon which to arrive at a conclusion, or else one or both are not honest." Now in this case we have engineers and scientists engaged upon both sides of it, men against whom no one would point a finger; yet they conscientiously have taken different views of the probability of damage to the city of St. Louis. Much was attempted by the aid of bacteriology; but I think I am safe in

saying that the bacterial demonstrations failed; and if there were any evidence of damage to St. Louis it was to be found in the mortality statistics of this city; and by those statistics and elements entering into the conditions which they exhibited the cause of St. Louis had to stand or fall. I think I am also quite warranted in saying that those in charge of the St. Louis case—I speak of the legal gentlemen—were very far from appreciating the importance of this factor in the problem. I am, I think, quite safe in stating that the mortality statistics of St. Louis and the factors which have a bearing upon them in the Mississippi, Missouri and Illinois valley, were not scrutinized with that care and thoroughness which they should have been to either establish or disprove the St. Louis case.

Leaving for a moment the question of the life of the typhoid organism, which of course was an important element in the problem, witnesses upon the Chicago side testified that there was no relation *apparent* between the curves of mortality in St. Louis and in Chicago. In this they were entirely justified. If they said absolutely that there were no such relation, I should be inclined to question, though perhaps not to contradict. The conditions of flow through the drainage canal and the Illinois River were such that at times water would pass from Robey Street down the canal to the intake at the Chain of Rocks in something like ten days. At other times conditions were such that it would require twenty-five days. There is a variation, you see, of over two weeks in the period. At one time an infection, if it were transmitted at all, might be brought down in ten days. At another period if it were transmitted at all it might require twenty-five days. Consequently, no fixed time element can appear between disease in Chicago and disease in St. Louis.

Another very important factor was the relative amount of water contributed to the Mississippi River at the Chain of Rocks by the three principal tributaries, the Missouri, the Mississippi and the Illinois. A study of the typhoid statistics of the city of St. Louis with reference to the volume of flow in the three streams showed that when the Missouri River was in flood, when the quantity of Missouri River water delivered was large in proportion to the supply from the other sources,

the typhoid infection in the water reaching the people of St. Louis was very materially reduced. The action in the settling basins of the St. Louis Water Works in the removal of all kinds of bacteria was very similar to that in a mechanical filter where a coagulant is introduced which causes the precipitation of impurities and bacteria at the bottom of the sedimentation basin, and when there was present an excess of Missouri River water containing a very large amount of sediment this material acted just as a coagulant acts, and removed to a very large extent, by its own settling, the bacteria present in the water. It appeared, I believe, that the range of removal in the sedimentation basins at St. Louis varied between 70 per cent. and 90 per cent. This fact also must have a very important bearing upon the relation of the curves of mortality in Chicago and in St. Louis, granting that there is any relation between the two.

Beyond this we have to bear in mind that there is a certain seasonable distribution of typhoid fever in all municipalities; that at certain periods of the year typhoid is prevalent, and at certain other periods it is comparatively absent; so that we would expect it to take a very considerable addition of infection in a water supply to change this seasonal distribution of typhoid, by reason of the fact that a very large amount of that seasonal distribution of typhoid is dependent upon other agencies than infected water. This again modifies the relation between the Chicago and St. Louis typhoid curves. And I now venture to say that when these various conditions are taken into consideration and proper allowances made, it is quite possible that a relation will be found between the prevalence of typhoid in the city of St. Louis and the prevalence of typhoid in the city of Chicago.

The statistics of typhoid in the city of St. Louis did show a quite decided increase after the opening of the drainage canal. In the year 1897 there were reported in the city of St. Louis 125 deaths from typhoid fever. In 1898 there were 95; in 1899, there were 130; in 1900, the year following the opening of the drainage canal, there were 168; in 1901, 197; in 1902, 222. In other words between 1899, the last year before the drainage canal was opened, and 1900, the first year afterward, the typhoid mortality increased in St. Louis from 22.1 per 100,000

to 28.5 per 100,000. The claim was set up by Chicago that this was due to the fact that typhoids which had previously been recorded as malaria, were after 1900 recorded as typhoids, following the discoveries made by the commission of physicians and surgeons appointed to investigate typhoid in millitary camps. That undoubtedly has some bearing, but the fact still remains that the total deaths from typhoid materially increased in St. Louis from 1899 on. Whether this increase is to be accounted for by the condition of the sewage of Chicago, or whether it should have been looked for elsewhere, is the point upon which, as I say, the investigations were not sufficiently exhaustive. It is true that an examination of the official records from a very large number of communities upon the drainage area of the Mississippi River was made, and that those records failed to show anything which would account for this increase; but we are all of us, I think, or at least those of us who have had occasion to investigate the ordinary mortality records of our western cities, in some doubt as to whether the actual status was established by this investigation. For instance, there was a rumor that there had been, about the time of the opening of the drainage canal, an epidemic of typhoid in the city of Alton, which is located a few miles above St. Louis, on the Illinois shore. I believe there was no question absolutely that there had been an epidemic of typhoid about this time in the city of Alton. Nevertheless, an investigation of that matter was made by one of the representatives of the city of St. Louis, and it was found that during the year in question there was only a record of a single death, not only in the city, but in the entire county in which Alton was located; that Alton in fact was the most salubrious dwelling place in the United States, according to the official records. While it is entirely possible that there were no deaths in Alton from typhoid fever, yet that would not preclude the possibility of infection of the waters of the Mississippi by typhoid from that source. Nevertheless, by the requirements of evidence, all that the court had to consider was the fact that according to the official records there had been one death in the county in which Alton was located, during the year—I believe it was 1900. As to what degree the statistics of other communities

may have been likewise defective, of course we have no knowledge; so that we finally are reduced to basing the St. Louis case upon the possible longevity of the typhoid germ under the conditions in which it was supposed to exist in the waters of the drainage canal, of the Des Plaines and Illinois Rivers, and of the Mississippi River.

The contention was made by Chicago that for a few years a certain quantity of Chicago sewage had been annually delivered into the Illinois River by way of the Illinois and Michigan Canal, and that there had been no effect from that, or at least nobody had complained, and that the addition of a somewhat larger percentage under a very much higher degree of dilution should not cause any criticism. This seems to be not an entirely tenable proposition in the light of evidence introduced upon her own side which the experts upon the St. Louis side were perfectly willing to admit; that is, that the typhoid germ would undoubtedly live longer in a pure water than it would in a highly contaminated water; and that the velocity of flow in the Illinois River as a result of the discharge of water through the Chicago Drainage Canal was considerably increased, it appearing that whereas the low water flow of the Illinois River before the opening of the drainage canal was something like 1400 cubic feet per second, the discharge after its opening was in the neighborhood of 5000 cubic feet per second; so that after the canal was open if infection came from Chicago it came with considerably greater rapidity at low water stages, and it came under conditions which would permit the life of the germ to be somewhat longer than under the conditions which existed previous to the opening of the drainage canal.

A point made upon the Chicago side which apparently had considerable effect upon the court, was that comparing the statistics for the five years previous and the five years subsequent to the opening of the canal there was not found any marked evidence of increase of typhoid mortality.

Now this in a measure was introducing in evidence only a part of the facts. Until within about a year of the opening of the drainage canal the pumping station at Bissell's Point in St. Louis, which was below the outlet of sewers serving a very considerable number of the residents of St. Louis, was in

use and was supplying water to the city; so that St. Louis for four of the five years in question had its water supply contaminated by its own sewage, and such a comparison as that above was not a fair one to establish the effect of water from the drainage canal, if water from there had any effect.

Now we come at last to this question of the longevity of the typhoid germ. There are experiments on record which show that in sterilized water of the Mississippi, of the Great Lakes, the Ohio River, and various other streams, the life of the germ is from forty to sixty days. There was other evidence to the effect than in ordinary river water, unsterilized, it would die in ten days. The time required for the passage of sewage from Robey Street to the Chain of Rocks was in times of flood a little less than ten days, and in times of low water probably not more than twenty-five days. It must be remembered, however, that the conditions that may be utilized in laboratory experiments we can hardly ever expect to fairly represent those which exist in a great river in nature; and whether the laboratory experiments showed that the germs would live, or that they would not, I do not consider the result conclusive when applied to such a proposition as the one in hand. So far as existing literature was concerned, there appeared to be two cases that might be considered in a measure comparable with the Chicago-St. Louis problem, in which it seemed that typhoid fever had been communicated under conditions which indicated a longevity of the germ sufficient for it to pass from Chicago to St. Louis. One of these cases was the Grand Forks epidemic and the other was an epidemic occurring in the city of Detroit in the year of 1892. These epidemics have been discussed in various places,* and it is not necessary for me to give the details further than to say that they were both caused by quite similar conditions, and stand somewhat unique among typhoid epidemics as being caused by such conditions. In the Grand Forks case a system of sewerage for the town of Crookston, about sixty miles up the river from Grand Forks, had been put in sometime previously. With characteristic Western thrift the contractor, it is said, had built a one-ring brick sewer where there was specified a three-ring. About the time they got the

* The Grand Forks Epidemic in Engineering News, 1895, Vol XXXIII, p. 341 et seq. The Detroit Epidemic Trans. Amer. Sec. C. E., Vol. XLII, p. 165 et seq.

plant in operation this sewer caved in. The city of Crookston had exceeded her credit, and the city's warrants were down to about 61, so that they were not able to repair the break immediately; and inasmuch as the people had not been accustomed to using sewers anyway, they thought it would not make much difference, and they put a four inch pipe past the break, and allowed the sewer to fill up with such material as accumulated there. It made a sort of septic tank, although I fancy there was not much free surface for the gas to work off in, and it had to pass away in solution through a four inch pipe out into the river. Finally times got better, and after a while the city of Crookston repaired that sewer, and having repaired it proceeded to flush out the sewer system. This happened in the fall—in November, if I remember correctly—and during the month previous there had been a very considerable amount of typhoid in Crookston. The river was frozen over at the time that this sewage was flushed out into it. The time of transmission was considerably less in this than in the Chicago case; for as I remember it now, it only required four or five days at the most for the water to get down to Grand Forks and contaminate the public water supply, which it evidently did, and caused one of the most severe typhoid outbreaks that this country has ever known; in fact, the number of persons who were taken sick in proportion to the total population was greater in that epidemic than in any other of which we have a record in the United States.

The other case, that of Detroit, was quite similar in nature, but perhaps more nearly comparable to the St. Louis conditions. This was caused apparently by the dredging of Black River at Port Huron, and the dumping of the dredged material in the St. Clair River at a point about 58 miles above the intake of the Detroit water works, and at a distance which required not less than seven or eight days, under the most favorable conditions, and very frequently required as much as 10 or 15 and perhaps even 20 days for the transmission of the water from one point to the other. Black River happens to be a stream that flows through the center of Port Huron. It receives sewers from both sides. Practically all the sewage of the city is discharged into it. It flows out into the St. Clair River, which has a comparatively rapid current for about 37 miles, when the

flow passes into Lake St. Clair, in which there is no current at all, or hardly any, for the next 17 or 19 miles, to the intake of the Detroit Water Works, passing through a broad shallow basin which has had to be dredged to maintain or create sufficient channel for the deep water navigation demanded on the Great Lakes at the present time. The lake is about 20 miles in diameter. The material from Black River was dredged by the Government, was dumped into the St. Clair River shortly below Port Huron, and in due course produced, according to the best of my belief, an outbreak of typhoid in the city of Detroit. It so happened that the percentage of dilution in this case was almost identical with that of the solids in Chicago sewage in the case of the Mississippi River. The volume of water in the St. Clair and Detroit Rivers was almost identical with the average of the Mississippi River at St. Louis. The amount of material discharged daily was almost identical with the amount of similar solid material discharged daily into the drainage canal at Chicago.

It may be argued that it has not been proven satisfactorily that the typhoid in Detroit was caused by the dredging in Port Huron. It is certainly true that nobody has succeeded in chasing the germs from one place to the other; nobody found any germs in the Detroit water at that time. A chemist analyzed it chemically and pronounced it entirely satisfactory. Nobody detected any undue amount of sediment in the river at that time. Nevertheless there was a very large amount of diarrhoea present in the city during that season. During the summer we had an outbreak of typhoid which became one of the important epidemics in the large cities of the country; yet by one of those strange fatalities of municipal statistics the effect of this was entirely obscured. The fiscal year ended on the first of July. This epidemic began on the fourth day of June. There were some 38 deaths from typhoid fever in the month of June, whereas ordinarily there were not more than four. The disease continued during July and August, and the expiration of the fiscal year divided it so that about one-third of it was charged up to the year preceding, and there does not appear a very startling amount of typhoid in the record of that year; while the rest of it went into the year following, and being distributed in the average for the whole year, it

did not produce any very marked impression; so that when you examine the health reports and statistics of typhoid in 1891 and 1892 there is nothing very striking about them, because that epidemic is divided in the middle and stretches over 24 months—when it ought to be concentrated in three months. When it is concentrated where it belongs, by taking the daily record of deaths, you will find that that epidemic vies with those of Pittsburg, and the one some years ago in St. Louis. I will not say that it vies with Chicago; we cannot touch that. As to whether that infection came from Port Huron or not, may be a question. I simply have to say this, that I worked on that epidemic for some two years in the endeavor to find some cause for it. It was one of those explosive epidemics that comes like a clap of thunder in a clear sky. For weeks previous to the outbreak there had been almost no typhoid recorded in Detroit. Suddenly we had four deaths in a single day, and we went right on having three or four after that daily for a considerable period. The indication was that this was due to some very decisive cause, something that had not existed before and that did not exist afterwards. I worked some two years on that. I made inquiries into the conditions of water supply in all the cities on the water shed. I corresponded with individual health and municipal officers relative to the presence of typhoid in their communities. I searched the health records and reports, both of the United States and Canada.

I finally threw up my hands and said that I could not find a cause to account for any such condition as existed.

At last the fact of this dredging came to my attention casually. I investigated. I found that taking the time of the flow of the stream from Port Huron to Detroit, taking the period of incubation, the time elapsing between taking the infection and the coming down with the fever, and the average period required for the disease to prove fatal, if the epidemic came in that way, its advent coincided within 24 hours of what we would figure out. It seemed to me that it was a conclusive case. But bear in mind even if this were so, that the amount of pollution in the St. Clair River was nowhere nearly so great as in the Illinois River, that it is entirely

possible, even though the typhoid may have come from Port Huron to Detroit—that in the case of the Chicago Drainage Canal the conditions affecting the life of the typhoid germ were such that it would have been destroyed much sooner than it would in the much purer water that was flowing in the St. Clair and Detroit Rivers. It does not prove the St. Louis case even though Port Huron to Detroit transmission is thought to be established. And when we get all through, the Supreme Court, I think, was entirely justified in saying that the evidence that was introduced was of a nature which fifty years ago would not have been permitted to be introduced in any case at court; in other words, the case was only proven, if at all, by circumstantial evidence. That was all that there was.

While it is my belief personally and individually that the discharge of the sewage of Chicago into the Illinois River did affect the water supply of St. Louis detrimentally, that it is or was a menace previous to the treatment of that water, still I cannot say that I regard that as proven; that is simply a conclusion that I have come to from my side of the case, from my knowledge of the collateral facts bearing upon such conditions. I presume I know more about the facts of this Detroit epidemic than anybody else, and if I hold a different conclusion in regard to it than other people, it is perhaps natural that I should. If other people say that that transmission has not yet been proven, I concede that they may be entirely right, that it may not have been proven to them; yet I think that most of them, if we should take the time to go into it honestly and carefully, go over all the ground that I went over, would conclude that while perhaps it was not proven, there was a pretty strong inference.

Now there is one other point that comes in here in regard to the life of the typhoid organism. If this typhoid germ was communicated to the Detroit supply as I suppose, it must have lived for a considerable period in the sewage deposits at the mouth of the sewers of Port Huron. Beyond that, we find the next spring when we had high water—we didn't have very high water, but the water rises perhaps a foot—that we had a considerable excess of typhoid again,

apparently due to the washing down of the typhoid material in some way. It may have come from out in the country around Detroit, around the water-shed of Lake St. Clair; yet statistics do not show that there was an abnormal amount of typhoid in the State of Michigan or in the surrounding counties at that time. There is nothing to indicate that there was any greater probability of typhoid infection being washed into the water supply of Detroit in the spring of 1893 than there had been in the spring of 1890, 1891 or 1892, or of any other year; and yet we had an excess of typhoid at that time. Now that may mean, of course, that typhoid-bearing material was deposited during the preceding year during those dredging operations, and that when the floods came it was stirred up and carried on down; or it may be accounted for in some other way. There is this to be said, however, that we have found by a study of Detroit's water supply and typhoid, covering the period from 1889 down to the present time, that whenever there has been a disturbance to the channel above the intakes, whether in Lake St. Clair or in the St. Clair River, or even as far up as the lower end of Lake Huron, there has been an excess of typhoid in Detroit; and whenever a year has gone by in which there has been no such disturbance Detroit has had low typhoid; and that is particularly interesting in the year 1890, for during 1889 there were considerable operations of that sort, and Detroit had what we would call high typhoid. During 1890 there were no such operations, and she had almost the lowest typhoid on record, and in 1891 when they began dredging again in Lake St. Clair and in the St. Clair River, Detroit had high typhoid again. So it has gone. Of course, whether these typhoid germs are living in the bottom of the river from month to month and year to year, or not, has not been proven in the laboratory; but if they are not, if they do not live so, it is rather difficult to explain some of these well established phenomena.

I thank you gentlemen, for your attention.

THE NATURAL PURIFICATION OF STREAMS.

By Edwin O. Jordan.

It may be safely assumed that there are few natural waters on the surface of the earth that do not receive a perceptible amount of the sewage, drainage, or waste resulting from human activity and habitation. Now the experience of the human race has shown that many of these natural bodies of water are used as a source of water supply by considerable populations without any strikingly noticeable injurious effects. If all the dangerous elements, or, to put it more specifically, all the pathogenic bacteria, entering bodies of water remained there in their original numbers without change it needs little imagination to picture the difficulty there would be in obtaining a supply of even moderately wholesome drinking water. We know that this is not the case, and it is apparent that in nature some sort of change occurs which results in the destruction or disappearance of the offensive and disease-producing elements that are introduced from time to time into most bodies of water

It has been wittily said that what is wanted in a drinking water is innocence rather than repentance, but it must be remembered also that very few large communities are in a position to obtain a virginally pure supply. In practically every civilized country the rivers, large and small, receive the sewage or drainage of a more or less extensive population, and the same is true of the large ponds and lakes. It has been estimated by Hazen that the water supplied to approximately 52 per cent. of the urban population (in cities of over 25,000) of the United States is unsatisfactory. The large and increasing consumption of water by the inhabitants of modern cities and towns renders the obtaining of a sufficient quantity of uncontaminated water always difficult and in most cases impossible. For the majority of public water supplies recourse is had to sources known to be more or less polluted at some stage in their history. The reckless practise of some cities in using such water without artificial purification shows that a considerable degree of natural purification must occur, otherwise the consequences of the neglect of elementary precautions would be far more disastrous than they are.

The extent and rapidity of this process of natural purification are, however, questions upon which there has been much difference of opinion among sanitarians, and concerning which existing data are inadequate and in some cases apparently conflicting. The final settlement of the question hinges upon many imperfectly understood and variable factors.

The problem is often presented in concrete form as follows: Suppose a city pours its untreated sewage into a river, how far below the point at which the sewage is discharged is it permissible or desirable on sanitary grounds for another city to take its water supply from this stream? Or, in another relation, in the case of a city deriving its water supply from a river, how far above this point can another city be equitably and safely allowed to empty its sewage into the river? Under actual conditions pollution and subsequent purification never present themselves in so simple a form. Between the point of great pollution and that of derivation of the water supply other sources of contamination and infection almost invariably exist. The drainage from rural communities or from isolated farm houses connected, it may be, with outhouses immediately overhanging the tributaries of the main stream, constitutes a perpetual menace to the purity of river water, even when the possibility of pollution with urban sewage is removed. These often overlooked sources of danger are, however, frequently overshadowed by the grosser defilement to which a stream is subjected by the discharge of the sewage of a great city. It is the latter event that is commonly considered, although perhaps unwisely, as the main feature in the problem of the natural purification of streams.

Stripped of all technicalities the question at issue in the suit on the Chicago Drainage Canal really is how far can typhoid bacilli travel in the water of a particular flowing stream and arrive in such a condition as, in the legal phrase, "to constitute a menace and a danger" to the inhabitants of a distant city or state. It is obvious that the problem is not one of space so much as of time, that it is not so much the distance over which a bacillus has to pass as it is the time consumed in traversing the stretch of river between the two points. The problem at bottom is essentially that of the longevity of the typhoid bacillus in a given water, whether of a river or a lake. As is well

known, the conditions affecting this longevity are many and varied, and the experimental evidence shows that the length of life of this micro-organism is greater in some waters than in others and is influenced by a variety of concomitant conditions. Practically, then, every inquiry into the alleged self-purification of streams must partake of the nature of an independent and separate investigation, and must for the present be carried on without too much reference to the results obtained under other conditions. It has rarely been found possible to experiment directly with the typhoid bacillus under conditions identical with those obtaining in a given river. It is therefore necessary to rely provisionally upon data of an indirect and inferential character, and it is these latter only that are ordinarily considered in a study of any particular case. The indirect evidence is of several kinds and of different degrees of value.

Evidence regarding the causation of typhoid fever is often most cogent on the epidemiological side. The sewage of the city of Lowell, Massachusetts, is emptied into the Merrimac river only nine miles above the intake of the Lawrence water works, and it has been shown that on several occasions a large amount of typhoid fever in the former city was followed by an increase in the disease in Lawrence, the correspondence in time being so close as to satisfy epidemiological requirements. Apparently a similar relation existed between an outbreak of typhoid fever in Newburyport and an unusual infection of the Merrimac by the sewage of Lowell and Lawrence respectively 26 and 17 miles above. (Sedgwick, Report Mass. State Bd. of Health, 1892, p. 701.) No such relation could be traced between the prevalence of typhoid fever in Chicago and St. Louis. If such a connection obtained it would be supposed that the curves of the disease would be much alike and that the St. Louis curve would be slightly retarded in time. As a matter of fact a comparison made by the writer of the published deaths from typhoid fever in these two cities by months and by years showed no relation whatever. Sometimes the Chicago minimum and maximum rates precede those for St. Louis by a period of from 2 to 11 months, sometimes they follow the latter, and sometimes they coincide with them. A similar outcome attended the attempt to connect high water or low water stages in the Illinois river with typhoid fever in St. Louis. An

interesting comparison was made between the months of July-November, 1901 and July-November, 1902. The water in the Illinois river was nearly twice as high in this period in 1902 as in 1901, and yet the amount of typhoid fever in St. Louis in the latter part of these years was almost exactly the same. Again there were 222 deaths from typhoid fever in St. Louis reported in 1902 and 225 in 1904 while in Chicago there were more than twice as many in 1902 [801] as in 1904 [373].

An examination of the monthly deaths reported from typhoid fever in Chicago and St. Louis between 1890 and 1904 inclusive showed that the mortality in St. Louis could not be related in any way to the extent of mortality in Chicago, to the season of the year or to the stage of water in the Illinois river.* In this crucial test the epidemiological evidence fails to reveal any connection, direct or indirect, between the prevalence of typhoid fever in Chicago and its prevalence in St. Louis.

The analytical data may next be considered. It is my opinion that the ordinary chemical sanitary water analysis, at its best of doubtful value, is not well adapted for throwing much light upon the problem of the self-purification of streams. The chlorine determination can have practically no significance, and even the determination of the nitrogen compounds is of little real importance. It cannot be said that the process of decomposition and the processes that lead to the destruction of dangerous bacteria run a strictly parallel course either in septic tanks or in polluted rivers.

It is also true that the mere number of bacteria in a water is no absolute criterion of the purity of the water. At the same time it must be admitted that the fate of typhoid bacilli introduced into a river is probably more closely correlated with that of other sewage bacteria than with oxidation changes in chemical constituents. The diminution in the numbers of bacteria in the Desplaines and Illinois rivers from Chicago to Grafton is shown in the following table:

*Record of Testimony, pp. 6278-6284.

DESPLAINES AND ILLINOIS RIVERS, CHICAGO TO GRAFTON.

Stations. Collecting	Distance from Bridgeport in Miles.	No. of Colonies per c. c.	No. of determinations.
Bridgeport	0	1,245,000	19
Lockport	29	650,000	30
Joliet	33	486,000	28
Morris	57	439,000	26
Ottawa	81	27,400	26
LaSalle	95	16,300	31
Henry	123	11,200	29
Averyville	159	3,660	30
Wesley City	165	758,000	22
Pekin	175	492,600	29
Havana	199	16,800	26
Beardstown	231	14,000	26
Kampsville	288	4,800	19
Grafton	318	10,200	28

There is no reason to suppose that the typhoid bacillus is any more resistant than the average sewage bacteria, and the enormous reduction in the numbers of the latter shown in the table would seem to indicate a similarly high and speedy mortality among typhoid bacilli introduced into a flowing stream.*

Special significance, in the judgment of the writer, attaches to the relative abundance of *B.coli* in a river water at different points along its course. This micro-organism, as is well known, is a normal inhabitant of the healthy human intestine and is found in large numbers in fresh sewage where, by appropriate methods, it is usually detected in each 1-10000 c. c. examined. A progressive diminution in the numbers of colon bacteria is observed in the samples of water taken at various points along the Illinois river from Lockport to Averyville, just above Peoria. At this latter point the colon bacillus is rarely found in 1-100 c. c. of the river water and is absent in 1 c. c. in about 25 per cent of the examinations. The considerable addition of bacteria to the river water from Peoria

*The longevity of typhoid bacilli in water as indicated by experiment is considered elsewhere by Professor Russell and the writer.

sewers, stockyards, and distilleries causes a temporary increase in both the total bacterial and the colon content; but this in turn disappears and *at Grafton, at the mouth of the Illinois river, the number of colon bacteria in the water is no greater than the number at Averyville* 160 *miles above, and no greater than the number in the various large tributaries of the Illinois.* If it be true that the fate of the colon bacillus in running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hesitation as to the conclusions to be drawn from this investigation. Since this near biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois river, there is reason to suppose that the typhoid bacillus itself does not long survive exposure to the same conditions.

Furthermore, when it is a question of comparing the condition of the Illinois river at its mouth with that of the Missouri river at its mouth and of the Mississippi just above its union with the Illinois, it is found that, judged by the colon content, the Illinois is about on a par with the Mississippi and notably superior to the Missouri. The characters of these several waters remain more or less distinct, in spite of some mixing, as shown by samples taken at approximately equidistant points across the Mississippi river at the St. Louis water intake. Photographs in the Record of the Case (pp. 6127-6130) illustrate the conditions there observed. All these facts indicate (1) That under the conditions prevailing in the Illinois river few if any typhoid bacilli live long enough to make the passage from Chicago to St. Louis; (2) That the water of the Missouri river, which constitutes by far the larger proportion of the St. Louis water supply, is, if weight be given to the colon content, more likely to contain disease germs than the combined waters of the Illinois and the Mississippi; (3) That in view of the discharge of untreated sewage into the Mississippi and Missouri rivers at Alton, St. Charles, and many other towns and cities much nearer to the St. Louis intake in point of time than Chicago, it is more reasonable to attribute any excess of typhoid fever in St. Louis to these near sources of infection than to any community, however large, situated at a remote point; (4) That the available evidence, bacteriological

and epidemiological, does not support the hypothesis of a connection between the opening of the Chicago Drainage Canal and the amount of typhoid fever in St. Louis.

Considered as a general proposition, the self-purification of streams has received more attention than its practical importance would appear to warrant. Under actual conditions implicit reliance on the natural purification of a river water is usually misplaced. A stream may conceivably rid itself of infection, if such infection be introduced at only one point, but may, nevertheless, be so exposed to contamination at other points along its course as to be totally unfit as a source of public water supply. Efficient control over the water sheds of such streams as the Mississippi, Illinois, and Missouri is obviously quite impracticable. It is only under such very unusual conditions as exist along the lower Mississippi that a river has a chance to work out its own salvation. If continuous contamination be withheld for a certain number of miles, or rather days, then "self-purification" may become a factor worthy of consideration. Such a condition is evidently rare.

The other extreme of opinion is equally untenable. Such an assertion as the following has been made, that "water once polluted is unsafe for domestic use unless artifically purified." No such sweeping statement can be justified unless based on a belief in the immortality of disease germs. All that we know about the bacteria of water-borne diseases goes to prove that they never multiply in water even when this is highly polluted, that they die out rather rapidly, and that even the few more resistant individuals lose their virulence and do not long retain their power of producing infection.

It may sometimes be difficult to determine which is the more reprehensible practise, discharging untreated sewage into a stream or lake or delivering unpurified water to a trustful public. Either procedure may be temporarily unavoidable.

The Chair introduced Professor Leonard P. Kinnicutt, Worcester Polytechnic Institute.

PROF. LEONARD P. KINNICUTT: The chief sanitary question in the case of the State of Missouri versus the State of Illinois and the Sanitary District of Chicago was, "Is the water of the Mississippi River so much more polluted by the additional amount of sewage conveyed by the Chicago Drainage Canal into the Desplaines River that it renders the water of the Mississippi more unfit for domestic use and more dangerous to be used as a source of a water supply at St. Louis than it was before the opening of the Canal."

There are two ways of approaching this problem. First, a careful study of the river before and after the opening of the canal, to determine what difference, if any, there is in the amount and character of the organic matter and the bacterial contents of the water at various points since the opening of the canal. Second, a careful study of the health conditions of St. Louis itself before and after 1900, and to determine therefrom if there has been any decided increase in zymotic diseases.

My own work on the case was the study of the condition of the water of the Illinois River, and from all obtainable data to ascertain if the opening of the canal had increased the amount of organic matter or the number of bacteria, especially the coli bacilli contained in a given volume of the water, and as to the probability of typhoid bacilli occurring in Chicago sewage surviving the journey from Chicago to St. Louis, including the danger of any such bacilli remaining in the mud deposit in the river, and at times of freshets being carried down the river to St. Louis.

To carefully review all the work that was thus required would occupy by far too much of your time, and I am only going to speak this afternoon of the results obtained from the study of the chemical and bacterial data placed in my hands. I may, however, possibly be allowed to say that from the investigations made, especially those of Professors Jordon, Russell and Zeit, it seems to me that the danger of the typhoid bacilli occurring in Chicago sewage ever reaching the intake of the St. Louis Water Works is so remote that it might well be considered as a negative quantity. Further, that the re-

sults obtained by the most careful study of the vital statistics of St. Louis, certainly did not prove conclusively, even taking the results furnished by the plaintiff, that there was a direct connection between the opening of the canal and the increase of zymotic diseases, and that "Not Proven" was certainly not too strong a conclusion to be drawn from the results obtained.

To turn now to my own work, the study of the water of the Illinois River from Joliet to Grafton was really a study of the self-purification of streams. We all remember the old statement, that running water purified itself in about 14 miles. We also remember the swinging of the pendulum the other way, and the statement in the Report of the 1874 Royal Commission on Sewage Disposal: "That there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

Work done since 1874 has shown both these statements to be incorrect. It was first shown that the destruction of sewage matter was due not primarily to the oxygen of the air but to bacteria. Then, that the most purification took place, not in running water, but in quiet or still water, and last, that it depended not so much on the length of the river, but on the ratio between the sewage to the river water, and the character of the river. The other factors remaining the same, the slower the flow, the greater the amount of purification.

I wish I had time to speak of the work of Dr. Frank; The examination of the River Spree above and below Berlin, or of Nieder's, the Sanitary Study of the Elbe below Dresden, or of Prausmitz's examination of the Isar above and below Munich, or of Stutzer's and Knulblanch's examination of the Rhine above and below Cologne, of Boyce's examination of the Severn before and after it received the sewage of Shrewsbury, all of which show the gradual purification of rivers after being polluted by sewage. This, however, would be out of place on this occasion, and I will merely give the results obtained by the chemical and bacterial work that was done in studying the effect of the sewage of Chicago on the water of the Illinois River.

The population of Chicago is, or was at the time the investigation was made, about 1,500,000, and the sewage was con-

sidered to equal 289 million gallons daily, which is about 28,359 cubic feet per minute. The sewage, however, was a dilute sewage containing about one-half the putrefying substances contained in the sewage of most American cities.

To prevent the pollution of Lake Michigan in the neighborhood of Chicago, the lake serving as the source of the water supply, the Sanitary Canal was built and in 1900 the sewage of Chicago, and at the same time 250,000 cubic feet per minute of Lake Michigan water was carried through the canal. The dilution, therefore, of the sewage by Lake Michigan water in the canal was as 1 to 8.8.

The effect of passing the sewage through the sanitary canal was similar to the effect that takes place in passing sewage through a septic tank. The action was anaerobic, namely, first the removal of the free oxygen dissolved in the Lake Michigan water entering the canal, and the combined oxygen in the nitrites and nitrates of the sewage, then in the partial removal of nitrogenous organic matter by deposition and in the decomposition of the deposited matter, as was shown by the increase of soluble nitrogenous matter in the water of the canal, at its outlet at Lockport, by the increase in the amount of carbon dioxide and ammonia the water contained, and the escape of marsh gas, carbon dioxide and hydrogen from the surface of the water.

The sewage of Chicago had, in fact, undergone a partial or preliminary purification before it entered the Desplaines River at Lockport. Unfortunately, we have not sufficient data to determine the effect on the bacteria of the passage of the sewage through the Sanitary Canal, though the experiments of Jordan, Russel and Zeit show at least that a very large proportion of the typhoid germs contained in Chicago sewage are destroyed during the passage of the sewage through the canal. This line of investigation, namely the action of the septic tank or pathogenic germs is one of very great importance for if it could be shown that pathogenic germs, especially the typhoid fever bacillus, is certainly destroyed by the septic tank process, it would avoid the necessity of special treatment of the effluent from the bacterial sewage processes, when such effluent must be emptied in streams, used as a source of a water supply, or

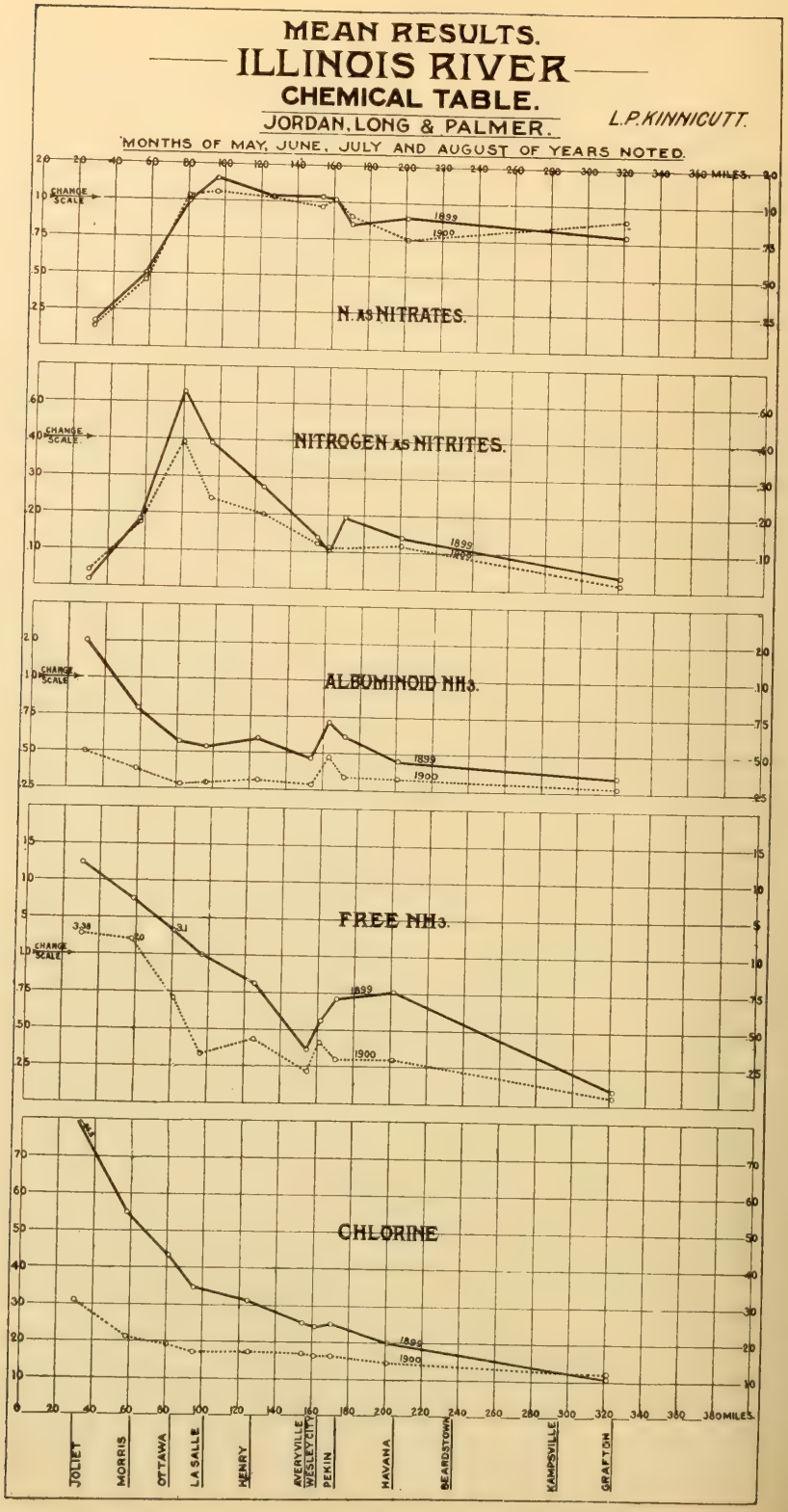
when the effluent is run into the ocean, in the neighborhood of shell fish beds.

As the sewage of Chicago leaves the canal it passes in a thin sheet over a dam 60 feet long and becomes more or less aerated and in a condition to be acted upon by aerobic bacteria.

The first point after the sewage left the canal where samples were taken for analyses was at Joliet on the Desplaines River, four miles below Lockport. These analyses show the amount of pollution of the Desplaines River which we can consider as the head waters of the Illinois River by the sewage of Chicago, and in the study of the self-purification of the Illinois River, the amount there found must be taken as the amount of decomposible organic matter that must be removed if the river is to purify itself.

In order to give an idea as to the purification that takes place I will throw upon the screen a chart which shows the amount of free ammonia, albuminoid ammonia, nitrogen as nitrites and nitrates, and the amount of chlorine at the various places where samples were taken, namely, at Joliet, north of Jackson street on the Desplaines River, at Morris, at Ottawa, at La Salle, at Henry, at Averyville, at Wesley City, at Pekin, at Havana, at Beardstown, at Kampsville and at Grafton on the Illinois River, from June to August, 1899, and during the same period in 1900. The abscissae give the distance in miles from Chicago, Joliet 33 miles, Morris 57, Ottawa 81, La Salle 95, (Peru) Henry 123, Averyville 158, (Peoria) Wesley City 165, Pekin 175, Havana 199, Beardstown 231, Kampsville 288, Grafton 318 miles.

The co-ordinates give the parts per million of the various substances, the results being the average of three different sets of weekly analyses made independently by Professor Jordan, Professor Long and Professor Palmer during the periods mentioned.


MEAN RESULTS.
ILLINOIS RIVER
CHEMICAL TABLE.
JORDAN, LONG & PALMER.
L.P. KINNICUTT.
MONTHS OF MAY, JUNE, JULY AND AUGUST OF YEARS NOTED.
N. AS NITRATES.
NITROGEN AS NITRITES.
ALBUMINOID NH3.
FREE NH3.
CHLORINE
CHANGE SCALE
1899
1900
MILES.
JOLIET
MORRIS
OTTAWA
LA SALLE
HENRY
AVERYVILLE
WESLEYCITY
PEKIN
HAVANA
BEARDSTOWN
KAMPSVILLE
GRAFTON

Tabulated, the results are as follows:

MEAN OF JORDAN'S, LONG'S AND PALMER'S RESULTS OF WEEKLY ANALYSES.

	Parts per million. May to August, inclusive.	
	1899.	1900.
Joliet.		
Free ammonia	12.68	3.88
Albuminoid ammonia	2.04	0.49
Nitrogen as nitrites	0.016	0.047
Nitrogen as nitrates	0.15	0.14
Chlorine	86.80	31.30
Morris:		
Free ammonia	7.40	2.00
Albuminoid ammonia	0.79	0.38
Nitrogen as nitrites	0.176	0.18
Nitrogen as nitrates	0.50	0.46
Chlorine	55.0	21.1
Ottawa:		
Free ammonia	3.1	0.70
Albuminoid ammonia	0.57	0.28
Nitrogen as nitrites	0.65	0.39
Nitrogen as Nitrates	1.01	1.14
Chlorine	40.3	19.10
La Salle:		
Free ammonia	1.0	0.33
Albuminoid ammonia	0.54	0.29
Nitrogen as nitrites	0.39	0.24
Nitrogen as nitrates	1.61	1.21
Chlorine	34.50	17.30
Henry:		
Free ammonia	0.81	0.43
Albuminoid ammonia	0.60	0.32
Nitrogen as nitrites	0.27	0.20
Nitrogen as nitrates	1.16	1.14
Chlorine	31.0	17.4
Averyville:		
Free ammonia	0.36	0.22
Albuminoid ammonia	0.47	0.29
Nitrogen as nitrites	0.14	0.12
Nitrogen as nitrates	1.15	0.97
Chlorine	25.3	17.00
Wesley City:		
Free ammonia	0.56	0.40
Albuminoid ammonia	0.72	0.48
Nitrogen as nitrites	0.10	0.11
Nitrogen as nitrites	1.06	1.09
Chlorine	24.30	16.60

	Parts per million. May to August, inclusive.	
	1899.	1900.
Pekin:		
Free ammonia	0.71	0.30
Albuminoid ammonia	0.62	0.35
Nitrogen as nitrites	0.19	0.11
Nitrogen as nitrates	0.86	0.91
Chlorine	25.10	16.60
Havana:		
Free ammonia	0.76	0.30
Albuminoid ammonia	0.46	0.34
Nitrogen as nitrites	0.14	0.12
Nitrogen as nitrates	0.91	0.76
Chlorine	20.00	14.80
Beardstown:		
Free ammonia	0.33	0.17
Albuminoid ammonia	0.49	0.36
Nitrogen as nitrites	0.22	0.15
Nitrogen as nitrates	0.77	0.88
Chlorine	9.20	11.60
Kampsville:		
Free ammonia	0.084	0.009
Albuminoid ammonia	0.51	0.36
Nitrogen as nitrites	0.14	0.05
Nitrogen as nitrates	1.01	1.01
Chlorine	6.2	11.20
Grafton:		
Free ammonia	0.10	0.05
Albuminoid ammonia	0.36	0.28
Nitrogen as nitrites	0.04	0.02
Nitrogen as nitrates	0.79	0.90
Chlorine	10.7	12.00

The chart thrown on the screen, comparing the state of the river in corresponding periods of 1899 and 1900, shows not only the amount of purification that took place, but also shows that the purification took place almost exactly the same way during the two periods, the two curves, one for 1899, the other for 1900, following each other very closely.

At Joliet the high free ammonia, the high albuminoid ammonia, taken with the low nitrogen as nitrites and nitrates, show at this point a water badly polluted by sewage. The rapid decrease in the amount of free ammonia, the albuminoid ammonia, from Joliet to Morris with the rapid increase of nitrogen as nitrites and nitrates, show the amount of purification that was

taking place between these two points. The most active zone of decomposition both in 1899 and 1900 was in the neighborhood of Ottawa as shown not only by the falling curves denoting free and albuminoid ammonia, but by the rise in nitrogen as nitrite and nitrate curves, the nitrogen as nitrites reaching its maximum at this point. That the zone of greatest decomposition should be at the same place both before and after the opening of the canal certainly indicated that the opening of the sanitary canal did not cause undecomposed sewage to be carried further down the river, a claim made by St. Louis.

As we proceed down the river from Ottawa to La Salle, the curves show continued purification. The slight fall in the curve for nitrogen as nitrates being due to removal of nitrates from the water by green plant life. From La Salle to Henry, the curves for free ammonia, and nitrogen as nitrites still descend. The slight rise in the curve for albuminoid ammonia and oxygen consumed indicate a slight addition of organic matter to the water of the river between La Salle and Henry. Below La Salle the purification continues down to Averyville, as shown by the gradual decrease of free and albuminoid ammonia, oxygen consumed and nitrogen as nitrites. At Averyville the chart shows the result of the final changes of organic into inorganic matter, low free ammonia and albuminoid ammonia, low oxygen consumed, with high nitrates.

At Wesley City we have the pollution of the river from the sewage of Peoria. The sewage of Peoria includes the sanitary and house sewage of about 55,000 inhabitants, to which there must be added a portion of the sewage from the 10,000 inhabitants of Pekin and the 8,000 inhabitants of various other small towns about Peoria. The substances contained in the house sewage constitute but a small part of the refuse matters which enter the river at or near Peoria, for vastly greater quantities of waste organic matters are derived from the various industries which find their center in this vicinity, particularly the breweries, and the distilleries with adjacent cattle sheds, the glucose factories, etc.

At Pekin and Peoria, according to Professor Palmer, from 40,000 to 50,000 cattle were formerly fed and at present 18,000 are fed upon distillery slops; the refuse from the stables nearly

all finds its way into the river, although in recent years a portion of it is filtered and the solid matters used as fertilizers.

The glucose factories use 50,000 or 60,000 bushels of corn daily, and the distilleries about 22,000 bushels, making a total of about 70,000 bushels of corn each day.

It is probable that from seven to ten per cent. of the weight of the corn used, including the larger part of the nitrogenous constituents of the grain, amounting to about two hundred tons of organic matter per day, passes into the Illinois River at Peoria and Pekin.

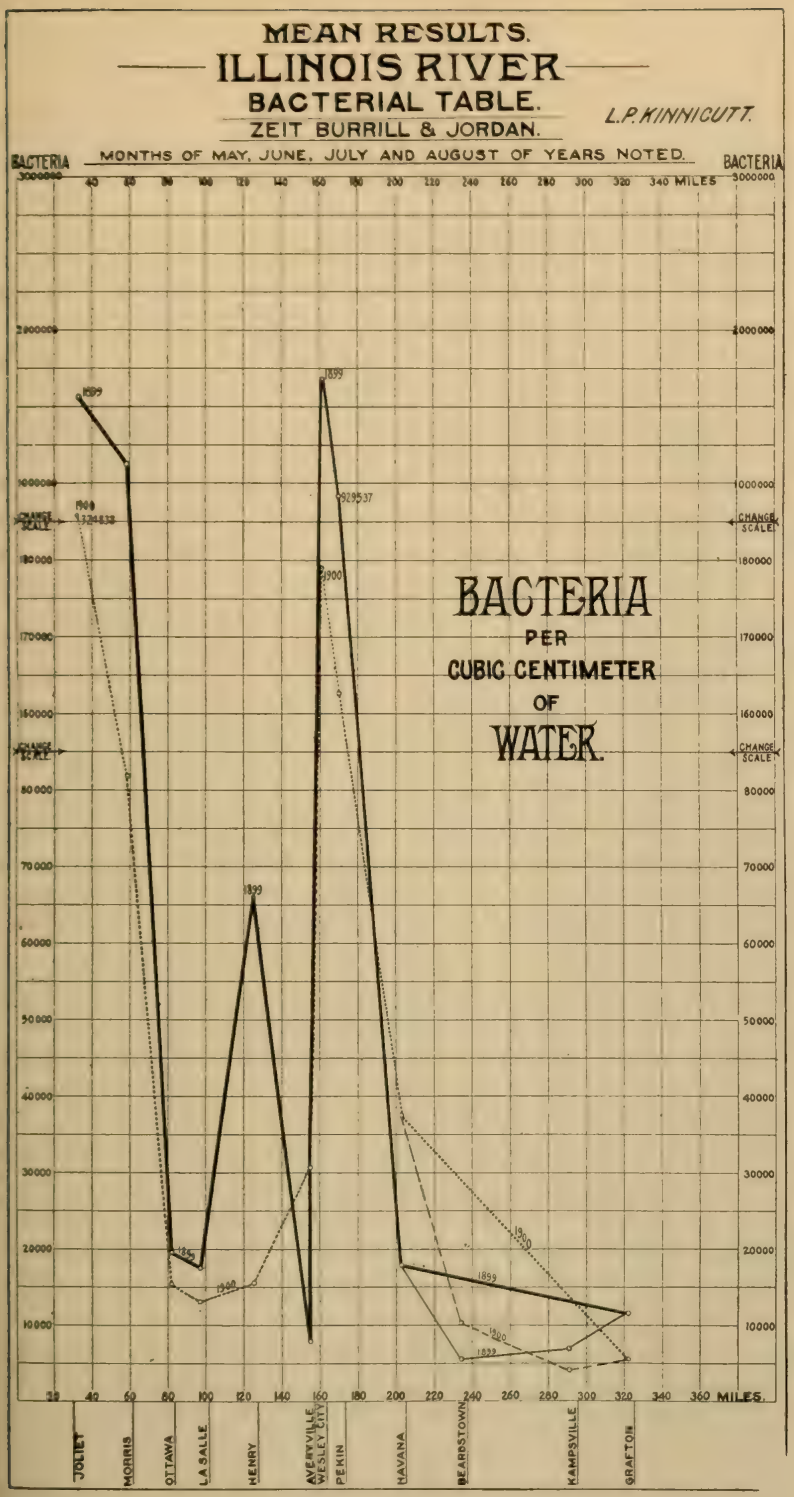
It would thus seem that the waste products introduced into the Illinois at these points are almost as much in amount and as offensive in character as are those introduced by the sewage of Chicago, and indeed in times of low water the condition of the Illinois River between Peoria and Pekin and below Pekin, was often fully as bad as the condition of the Chicago River in the times of its most notorious offensiveness.

The pollution entering the river at Peoria is shown by the rise in the curves showing nitrogen as free ammonia, albuminoid ammonia, and nitrites, and in the fall of the curve, showing nitrogen as nitrates and the rise in the curve denoting chlorine. Between Pekin and Grafton, 143 miles, there is a repetition of what took place between Morris and Averyville, a gradual disappearance of the polluting substance, and a purification of the water, the pollution of Peoria disappearing as the pollution of the sewage of Chicago disappeared above Peoria, a double purification of the river is thus shown; the first purification in the 132 miles between Joliet and Peoria, the second purification between Peoria and Grafton, 153 miles.

All the data given on the chart show, as I have stated, not only that the purification of the river in both years took place exactly in the same way, but also, which is still more important, that the river at all points contained per unit volume less organic nitrogenous matter during May, June, July and August, 1900, than during the same months of 1899.

As to the chlorine curve, it shows approximately the increase of volume of the river water from Joliet to Grafton except at Wesley City where its rising shows the effect of the pollution from Peoria.

Chart No. 2, which I now throw on the screen, gives the bac-


MEAN RESULTS.
ILLINOIS RIVER
BACTERIAL TABLE.
ZEIT BURRILL & JORDAN.
L.P. KINNICUTT.
MONTHS OF MAY, JUNE, JULY AND AUGUST OF YEARS NOTED.
BACTERIA
BACTERIA
PER
CUBIC CENTIMETER
OF
WATER.
CHANGE SCALE
MILES
JOLIET
MORRIS
OTTAWA
LA SALLE
HENRY
AVERYVILLE
WESLEY CITY
PEKIN
HAVANA
BEARDSTOWN
KAMPSVILLE
GRAFTON

terial content of the Illinois River at the places named during May, June, July, August, 1899 and 1900. The results being the mean average of independent series of weekly analyses made during these months by Professor Burrill, Jordan and Zeit.

	Bacteria per cubic centimeter. May to August, inclusive.	
	1899.	1900.
Joliet	1,534,350	324,838
Morris	1,136,107	81,903
Ottawa	19,426	14,992
La Salle	17,388	13,288
Henry	66,188	16,026
Averyville	7,609	30,690
Wesley City	1,680,870	179,654
Pekin	929,537	163,180
Havana	17,741	37,484
Beardstown	5,525	10,378
Kampsville	6,953	4,159
Grafton	11,163	5,348

The curves show the bacterial contents of the river between Joliet and Grafton as obtained from the results of Burrill, Jordan and Zeit, for the months of May, June, July and August, 1899 and 1900. Both curves show a great number of bacteria per cubic centimeter at Joliet; they then show a great decrease between Joliet and La Salle, a distance of 65 miles. The curve for 1899 shows that between La Salle and Henry the number of bacteria increased rapidly, owing possibly to the sewage of La Salle and Peru, but decreased almost as rapidly between Henry and Averyville. The curve for 1900 shows also that there was a slight increase in bacteria between La Salle and Henry and also a further slight increase between Henry and Averyville, due probably to some local cause.

Between Averyville and Wesley City the two curves show a very rapid increase of bacteria in both years, greater, however, between Wesley City and Pekin in 1899 than in 1900. In both years the curves show a very great decrease between Wesley City and Havana, a distance of 40 miles, and the decrease continued, though not so rapidly, between Havana and Beardstown. The curve for 1900 shows this decrease continues to Kampsville, while the curve for 1899 shows a slight increase in bacteria for that year between Beardstown and Kampsville.

In both years the curve shows a slight increase in numbers of bacteria between Kampsville and Grafton. The curves show only three places in the river where the number of bacteria was greater in 1900 than in 1899, namely at Averyville, Havana and Beardstown. The number of bacteria at Grafton is shown to be about 6,000 less per cubic centimeter in 1900 than in 1899.

I am sorry that I have not also a chart showing the relative abundance of the coli bacillus at different stations along the Illinois River because, as Professor Jordan has stated, they are of special significance in studying the removal of pathogenic germs by the self-purification of streams.

The chart that I made followed in a general way very closely the chart that I have shown giving the total number of bacteria at various points, the greatest number at Joliet, gradually decreasing till Averyville is reached, where coli were seldom found in 1-100 of a cubic centimeter of the water, a large increase at Wesley City, owing to pollution entering the river at that point, again decreasing in number till in the water of the Illinois at Grafton there was no greater number than at Averyville, 160 miles above.

The two charts that I have prepared give only a general idea of the analytical work done in trying to solve the question regarding the destruction of the organic matter, and the removal of the bacteria from the sewage of Chicago by the process known as self-purification of streams. That a very great amount of purification does take place is without question, and the amount as shown by the above data is so great that I believe that if the sewage of Chicago was the only pollution of the Illinois River and especially if the refuse from Peoria did not enter the river, the only evidence at Grafton that the river had ever received sewage would be high nitrogen as nitrates and chlorine much above the normal.

I have already spoken too long to enter into any discussion as to the cause of the removal of the organic matter and bacteria from the water of the Illinois River, but the chief factor is deposition due to the fact that the fall of the river from Henry to Grafton, a distance of 225 miles, is only 30 feet, that the banks are low and the water spreads over a large tract of country, that at Joliet and above Peoria there are wide ex-

panses of the river, forming in fact what might be called lakes. that below Peoria there is a continuous series of ponds or lakes, and that the whole lower part of the river, especially at times of high water, resembles a lake more than a river.

Mr. Rudolph Hering: Mr. Chairman and gentlemen of the American Water Works Association:

As I am in a small measure responsible for the course of events which led up to the construction of the Chicago Drainage Canal, it may be interesting to restate briefly the conditions under which it was recommended, its dimensions and levels.

There were only three ways to properly dispose of the sewage. One was to purify it by intermittent filtration on sandy soil; the second way was to treat the sewage chemically, in other words, partially, to discharge the effluent into the southern part of Lake Michigan, and then to move the water works intake to what is called Grosse Point, a point of land jutting out into Lake Michigan some 12 miles, or perhaps more, north of the center of Chicago; in other words, to have the two points of the water intake and the sewage outflows as far apart as possible.

There was a third way possible in Chicago, not possible in many places on this earth. Chicago lies practically on the water-shed between the St. Lawrence River and the Mississippi River. Should the lake have risen five feet some of its water would have flowed into the Gulf of Mexico at that time. Mr. E. S. Chesbrough, formerly City Engineer of Boston, and who was later City Engineer of Chicago, in the fifties, said that some day Chicago would throw her sewage into the Mississippi River. This idea was carried out very soon afterward by the construction of the Illinois and Michigan Canal, which united the waters of Lake Michigan with the Illinois River. The sewage of Chicago being discharged into the river was, together with the river water, recommended by the State Board of Health to be lifted by pumps and thrown into the Illinois and Michigan Canal, and thence to flow down the Illinois River.

That was the state of affairs in 1886 when I was appointed Chief Engineer. The canal was an improperly arranged septic tank and it was extremely foul. South Fork, which is a branch

of the Chicago River, where the stock yards discharged all their filth, was also a septic tank; there was a scum on it about two feet in depth; in fact, men were known to have walked across this river on the scum. In summer it was dusty on top, so that you could not distinguish it from the adjoining prairie.

We organized parties to investigate at once all these propositions. The lake currents were observed, their directions and velocities, and as much other information was obtained as practical during that time, to find out the character of the currents in the lake. I may right here state a few results, particularly as I saw charts of the lake here yesterday bearing upon this subject. We found,—and the information was confirmed by the tender of the crib station for many years,—that the currents of Lake Michigan on the west side near Chicago went about as often to the north as the south. We made float observations, using surface floats, mid-depth floats and bottom floats, to see how the currents were at different depths. We found that they were caused chiefly by the wind. Sometimes the wind would change and the surface float would go one way, and the mid-float and the bottom float would go the other way, till if the wind prevailed long enough they would gradually all run together in one direction. These records were kept for a year; they indicated that the currents moved about as often one way as the other.

We also established automatic self-recording gauges and got the height of the water on both sides of the lake as well as further down the lake. From these we observed that the oscillations, which are fairly regular in the lake, indicated about a twenty-minute period. At one time the record showed a sudden drop of two feet eight inches, and then a rise to above the mean level; then a continuance of the swing until gradually the ordinary conditions were resumed. It was interesting to learn the cause. This was found to be the moving over Lake Michigan of a center of low barometer, which traveled at the rate of about 1,000 miles a day; and just about the time when the Signal Service records showed that it should have been over Lake Michigan we noticed this drop at the lake shore of about two feet eight inches within five or ten minutes.

Disposal of the sewage by filtration was investigated by means of surveys of soil and land and estimates of cost. It required a very large amount of pumpage—I think about 90 feet—in order to get the sewage down to the land south of the lake, and many miles of outfall sewers.

The last proposition was the present Chicago Drainage Canal. As it was quite a new problem, and considering the great length of this canal, 28 miles and largely through rock, it was very important to find out how large to make it so as to be suitable for all purposes, also on account of the great expense. It was first necessary to find out how much water was required to so dilute the sewage that it would give no offense either in Chicago or below. We had then no information bearing on that subject, excepting at the following places:

The first and most important place was Chicago itself. How did the sewage act when it went through the Illinois and Michigan Canal and then into the Des Plaines River, was there diluted, went down to Peoria, and finally into the Mississippi? I might state that 80 per cent. of the Chicago sewage went through the old canal before the new drainage canal was recommended. Through Dr. Long and Dr. Rauch, Secretary of the State Board of Health, many observations were made, but they are all of a chemical nature. Dr. Rauch, I may say, was the first one to my knowledge who recommended a certain relation between flowing water and the amount of sewage in order to measure the offensiveness of the pollution. In his experiments and in his observations throughout the state he found that it was necessary to have a certain amount of water flowing through the Illinois and Michigan Canal to properly dilute the sewage of Chicago. Dr. Rauch's conclusion was that there should be a flow in the canal of 180 cubic feet per minute for every 1,000 persons sewering into the same.

Another river that furnished information was the Blackstone River in Massachusetts. There we had a record of the dilution by the sewage of Worcester, and of the flow of the Blackstone River, and could determine at what point the dilution made the sewage no longer offensive. The result was that when there was a flow of 140 cubic feet per 1,000 persons in

that river it was, according to the reports, practically inoffensive.

In Europe I found the Oder at Breslau to furnish similar data, and also the River Seine at Paris; where a certain distance below Paris, after receiving most of its sewage, the river was practically clear and quite inoffensive. When it flowed at the rate of 60 cubic feet per minute per 1,000 persons there was still no odor. There was none at double this flow.

Now, in order to be safe and not injure the people of Lockport and Joliet, large and growing towns, we concluded that the canal should be constructed to carry an amount of water of 240 cubic feet per minute per 1,000 persons, or 4 cubic feet per second per 1,000 persons. That was the figure which established the size of the Chicago Drainage Canal as it has been built and calculated for a population of 2,500,000. Later it was thought that 3 1-3 cubic feet per second per 1,000 persons was probably enough, thus providing for 3,000,000 people.

The main causes of the apparent disappearance of the sewage matter we considered to be dilution, subsidence and oxidation. Dilution I have already mentioned. Subsidence we exepected to be brought about in this way: The velocity was to be kept low on account of the proposed navigation in this canal; therefore, we expected deposit in the upper region of the canal, which would have to be dredged out. Then we expected that there would be a disappearance of organic matter by oxidation.

Studies that were made from the data of European and American rivers and by plotting profiles or the quantitative flows at different points, showed very distinctly from the chemical analysis that the chief cause of purification was the dilution caused by the additional amount of water coming in from the streams and from the springs in the river bed. The oxidation on the other hand was slight though quite perceptible. Now we know that this oxidation is chiefly obtained by bacterial action.

I shall now say a few words about the late controversy in which also I was a witness. It was a question as to whether this canal was injuring St. Louis. With the assistance and

better knowledge of bacteriology, and based on many observations that have been taken since the canal has been projected, I thought it would be well to see how the effect of the Illinois, the Missouri and the Mississippi rivers would compare at St. Louis, considering the amount of sewage received at different points. So I had a profile made of the Missouri from Omaha down to St. Louis, a profile of the Mississippi River from Minneapolis and St. Paul down to St. Louis, and a profile of the Illinois River from Lake Michigan to St. Louis. These profiles are published in the evidence. I am sorry that I have no copy here. They are interesting in several ways. One is that you will notice the profile of the Missouri River to be very much steeper than that of the Mississippi and the profile of the Illinois River from Lockport down to be very much flatter. An estimate was made of the mean velocity down the Missouri River, the mean velocity down the Mississippi River and the mean velocity down the Illinois River. It was found that the water from Omaha reached St. Louis in 11.6 days; from St. Paul in 15 days, and from Chicago in 18.5 days.

In order to apply this information to the question at hand I used the data obtained by Mr. Hiram S. Mills of the Massachusetts State Board of Health, on the longevity of the typhoid bacillus, and found that the bacilli arriving at St. Louis were in this proportion: Thirteen from the Illinois River and Chicago, 96 from the Missouri and 107 from the Mississippi. These figures were obtained by taking the population in all cities along those rivers, and supposing that the typhoid fever was in the same ratio everywhere. Thus we get a proportionate idea of the relative dangers from infection in those three rivers owing to the relative velocities of their water. This showed that the Illinois River produced decidedly the least effect if any upon the St. Louis case.

I should also point out that while for sewage purposes it is found that the Chicago Drainage Canal was the cheapest of the possible ways of disposing of the sewage it should also be credited by two advantages which were not estimated in dollars and cents, but which were valuable. One was that this canal can establish a water-way for large boats to go from Lake Michigan through the Illinois River down to the Gulf of

Mexico through the Mississippi River—a matter of great commercial importance. It was also found by calculations that it would raise the low water flow of the Mississippi River about 12 inches, which is a matter of no small importance for the navigation of that river. This possible navigation from the lakes to the Gulf of Mexico was a strong factor in the recommendation of that system. The continent of Europe is spending many millions in establishing new waterways connecting north, east, south and west. It is to be expected in time that we shall also do this , and there is no better way to connect the Gulf of Mexico with the lakes than through this Chicago Drainage Canal. That fact is appreciated by the city and will probably help to carry the project through. Much of the expense, I wish to say, that the canal has cost will go to make it applicable as a ship canal, instead of only for drainage purposes. We could by much less money expenditure have designed a channel at a steep grade which would shoot the diluted sewage down to Joliet; but that would have made navigation, of course, impossible. Therefore, when one hears of the large expense of this canal it should not be forgotton that a large portion of it should be credited to making it available for navigation.

One other point I want to speak about, and that is the result of the examination of the St. Louis charts of mortality for typhoid fever. Any one examining those charts will see that there is a distinct rise in the death rate in the autumn—late summer and autumn. I think that is shown on the charts that were passed around. This peculiarity of typhoid fever occurs all the world over. You can see it also in Europe. Dr. Pattenkofer took it up and tried to explain it, but in a way different from what we do to-day, because he didn't have the advantages of bacteriology. The rise in the death rate in the autumn is due to insects, probably flies. That opinion was first expressed in our country a few years ago, and is now being held also in Europe. When we see those annual curves in St. Louis before and after the opening of the Drainage Canal and compare them with similar charts of other cities, we can safely conclude that they have nothing to do with the Chicago sewage discharge. Therefore I feel that the Chicago Drainage Canal

ought not to have been impeached, for it was doing good work, and that the future will further show that its construction was a proper recommendation to make to the City of Chicago.

MR. GEORGE W. FULLER.

Mr. President and members of the Association:

It is difficult to speak in brief terms of the Chicago Drainage Canal case. This is partly due to the large number of different lines of evidence of a bacteriological chemical and engineering nature. It is also due in part to the relationship of this evidence to the legal aspects of the case; in other words, to appreciate this matter as it was developed in the trial it is necessary to understand somewhat the attitude of the legal advisers in charge of the case.

From the St. Louis standpoint, that being the side of the case with which I was connected, there are several matters from the standpoint of policy which differ much in the way in which they were first regarded from what they were later on, and particularly as viewed after the court has rendered its decision.

It might also be worth while saying a few words as to the conduct of the case. It is no discourtesy to the legal advisers of the State of Missouri to say that they were handicapped in having half a dozen different men conducting the legal aspects of this case during the six years that the case was pending; and it also might be mentioned that they were handicapped somewhat by financial reasons, and in general were unable to present their evidence as satisfactorily as Chicago, where with a board of trustees and with a continuous set of advisers, both legal and engineering, they could map their case out in a much cleaner-cut way.

There are two aspects of this drainage canal case that I wish briefly to mention. The first one is that of the legal interpretation to be put upon the case by virtue of the city of Chicago being off of the natural water-shed of the Mississippi River. It was thought by the St. Louis and Missouri lawyers that it would be sufficient to show that the city of Chicago, being located on a different water-shed, should naturally take its sewage elsewhere than streams tributary to the Mississippi above St. Louis. Legally that meant much, and if that attitude

had been supported by the court it would have put the burden of proof largely upon Chicago after it was established before the court that this ditch was cut through the divide. The St. Louis lawyers had considerable reason, I am told, for taking that attitude, when Chicago's demurrer to this case, in 1900, was overruled. As all of you know who have read Professor Mason's very interesting paper, the court did not take that attitude on that question.

There is one other aspect as to the policy adopted in conducting the case; that is the relationship of the old Illinois and Michigan Canal. A great many of these data have been computed and interpreted from the standpoint of the quality of the water in the Mississippi River and at various other points before and after the opening of the new drainage canal. By some it has been claimed that there is very much less organic matter coming from Chicago into the Mississippi now than there was before this new canal was opened. Whatever may have been the legal merits of that proposition, it was the policy of the Missouri lawyers to state, and so far as they could to gather evidence in such shape that Chicago was to face this proposition: i. e., that if all the pollution of the Mississippi above St. Louis were to be eliminated other than that coming from the city of Chicago, would the sewage of Chicago then interfere with or seriously contaminate the water supply of St. Louis and other towns and cities in the State of Missouri? Associated with that proposition of the effect of the Chicago sewage upon the typhoid fever statistics in St. Louis, was the point which has been mentioned several times this afternoon, and that is that the old Illinois and Michigan Canal contains sewage which is diluted so little that it is practically a septic tank. This has been mentioned by Professor Kinnicutt and others, who claim that the typhoid fever germs in the midst of all the bacterial decomposition going on in this canal, naturally would be eliminated to a very large degree.

These two aspects above mentioned had a great deal to do with the manner in which the evidence was presented during the portion of the time when I was connected with the case.

There are three phases of this, and in fact of all problems for the disposal of sewage. One is the question of whether

there exists a gross nuisance; that is, decomposition to the point where foul odors result. It is safe to say that there has been no such condition resulting so far as the Chicago sewage passing through the new canal is concerned. I think that has been conceded by every one.

The second phase is that of whether the sewage from Chicago adds to the Mississippi River water an amount of organic matter of a crude nature and in such quantities that it has direct relation to the health of the people living on the banks of the river. On this point, too, it is probable that there has been very little to show that the Chicago sewage is a menace along the Mississippi River. It is probable at times that crude organic matter from Chicago sewage does reach the Mississippi. That is particularly true during the winter months when bacterial agencies are less active than they are during the warmer seasons of the year.

But here I may mention what is perhaps one of the most striking things, scientifically speaking, in connection with this whole investigation, and that is the utter inadequacy of analytical methods which have served their purpose so well in many of the larger problems of Europe, and which have been so effective in studying problems here in Massachusetts particularly. It is probably a surprising fact to many of you to know that the ordinary methods of analysis during a large number of days and weeks, perhaps months in the year, are incapable of showing the effect of the St. Louis sewage upon water flowing in the Mississippi River.

That can be shown in two ways: you can take the average analyses of a large number of samples which represent a thorough cross section of the river near the Chain of Rocks, six or eight miles above the city, and you can take corresponding samples representing a complete cross section of the river below the city; upon comparing the averages above and below the city, there are many times when you are unable to show any effect of the St. Louis sewage upon the water of that river.

Another way of getting at the same point is to take the weight of organic matter which is contributed to sewers by each person daily. Then take the total population contributing sewage at a given point and figure the dilution by the enormous

volumes of water such as passing by St. Louis in the Mississippi you can confirm this statement which I have just made. The resulting dilution is so great as to be beyond the limits of accuracy of chemical analyses.

There is still another aspect showing more forcibly than anything else that I know of what has been demonstrated in this case, and that is the inability to tell whether organic matter comes from a vegetable origin, or whether it is of animal origin. In the instance of the water flowing from the mouth of the Illinois River it is practically impossible to tell how much of that organic matter comes from the soil, how much from the stock-yards of Peoria, and how much from the Chicago sewage.

The real problem in connection with the Chicago Drainage Canal is this: Do the disease germs coming from the Chicago sewage pass down the river and enter the Mississippi and pass along the shores of the State of Missouri? That has been said, as you have been told this afternoon, to be statistically evidenced by the records of typhoid fever mortality of St. Louis and other portions of the water-shed, and also from the standpoint of the longevity of typhoid fever germs in water. It is safe to say that the great majority of the typhoid fever germs coming from the city of Chicago die before the sewage containing them reaches the city of St. Louis. The point at issue is this: Is there a sufficient number remaining to have a material effect upon the water of the Mississippi along the shores of the State of Missouri? The various laboratory experiments which have been mentioned and cited in evidence in this case, and referred to this afternoon, have been conducted by men of great skill and of wide experience in this line of work. I think that there has been a marked step in advance taken in the accuracy with which these data have been obtained; but the difference in point of view of the experts from the St. Louis side as compared with those on the Chicago side relate to the interpretation of data which are fairly well agreed on. They are substantially this: Typhoid fever germs enter a water where they are materially diluted, and it is found that the great majority of them die in one day, one week, ten days or possibly two weeks, and still the fact remains that some of them are still living at the end of quite a number of days. To a

person who is doing that work in the laboratory and is familiar with that class of work it is not necessary for me to state that I am speaking of the final results being regarded as negative when the actual results of analysis simply fail to give a positive result.

In all of this work it is necessary to employ small volumes of water in order to get the bacterial numbers reduced to a point where they can be readily handled. It is true that with the most modern and improved methods with which we are now familiar, it may be found that after a period of ten days there are few or no typhoid fever germs in any receptacle containing water to which such germs are added; but this is not clean-cut proof that those germs are entirely gone. That is a point of difference between the Chicago and St. Louis experts in this case.

If the water coming from the mouth of the Illinois River containing Chicago sewage and also sewage from any other community, should be found by analysis to show no typhoid, it does not prove that typhoid is absolutely lacking. Now then whether one or two per cent. of typhoid fever germs, originally present in Chicago sewage, occasionally pass through the Illinois River and down to the Mississippi at St. Louis, I do not think any one can tell us accurately; but from my experience in that line of work, and from my appreciation of the mathematical limitations of such data, there is no doubt in my mind at all but what there is quite an appreciable amount of typhoid fever germs coming in from the Chicago River into the Mississippi River. No one knows what that percentage is. It may be one-tenth of a per cent. on one day; it may be practically nothing at all on other days; it may be one per cent., two per cent. or three per cent. the day before that. For instance, say that we take one per cent. of the pollution of Chicago, that has 2,000,000 people all discharging sewage down toward the Mississippi River; in passing St. Louis we may then say that there is added the sewage of 20,000 people. That is a point upon which the Chicago Drainage Canal case was rested to a considerable extent.

In this case considerable testimony was given as to the practical bearing of a small and varying percentage of Chicago

typhoid fever germs entering the St. Louis water supply. I may add here in further explanation of this proposition that it was recognized that those typhoid fever germs became deposited in the sediment and do not go down at a uniform rate; but this sediment is subject to varying velocities, and would therefore reach St. Louis in an irregular manner. It seems to me then that at times there would be a much greater influence on the Chicago sewage than at others. This evidence has not been considered by the court sufficient to be of consequence; and it is not surprising, in view of the legal relations which follow if the cities of Chicago, Minneapolis, Omaha and Kansas City, etc., are joined in responsibility; a responsibility which was allied to that of St. Louis herself, from the standpoint of New Orleans and cities further down the valley in regard to the general proposition of filtering the water and increasing contamination.

As to typhoid fever germs, it is true that it does not make a great deal of difference, within certain limits, if the amount of specific infection is increased. There has been sufficient experience with filtration both in this country and in Europe to show that it is a greater responsibility, a proposition involving more money to get equal results as to purity of effluent, when you are filtering a badly polluted water than when you are filtering a less polluted water. With increasing pollution in coming years there will be an increasing responsibility and expense of purification.

Mr. Allen Hazen: Mr. Bright, who took the testimony for the Court in this case, stated when it was all in that he had taken 13,669 pages of evidence, of which he thought 69 were relevant.

A very large proportion of the other 13,600 pages were devoted to the life history of this typhoid bacillus about which we have heard so much this afternoon.

The strongest and clearest statement of the case, as represented by the experts employed by Chicago, is found here in Professor Jordan's paper, where it is stated: "Stripped of all technicalities the question at issue in the suit on the Chicago Drainage Canal really is, how far can typhoid bacilli travel in the water of a particular flowing stream and arrive in such a

condition as, in the legal phrase, 'to constitute a menace and a danger' to the inhabitants of a distant city or State?"

Now, I contend that this theory of the case is all wrong. The question is not how far typhoid bacilli can travel. The real question is whether the sewage of Chicago is injuring the people of St. Louis.

The eminent counsel of the Chicago Drainage Canal stated the case far more truly when he said, in talking the matter over with us one night after the hearing: "The only important point in the whole case is that the people of St. Louis do not like to drink Chicago's excrement."

Before the Chicago Drainage Canal was opened the sewage of between one and two millions of people went into the waters from which the St. Louis water supply was taken; and the presence of that sewage was regarded by the people of St. Louis as a serious matter.

It was proposed to spend many millions of dollars to get water from a place where the sewage would not be present, and much time and effort were spent to find means within the reach of the city for accomplishing this end.

Even the eminent engineers and bacteriologists employed by the city of Chicago in this suit would not claim that the sewage of a million odd people, discharged into the Mississippi River and its tributaries, was beneficial to the water supply of St. Louis. I venture to believe that some of them would even go so far as to admit that it was distinctly injurious.

The opening of the Chicago Drainage Canal fully doubled the amount of sewage in the water supply at St. Louis.

It is a matter of general experience that sewage entering a public water supply increases the death-rate and the amount of sickness among those who use the water. The studies that have been made indicate that of all the sickness and death caused by a polluted water, not more than one-fourth can be accounted for by typhoid fever or by this typhoid bacillus.

The bacteriologists are very clever fellows. They have made great progress in studying typhoid fever and in learning how it is transmitted from one person to another, but they have not accounted for the three-fourths of the deaths that come from the sewage present in a public water supply; and so far as I know, they are unable to do this.

To limit this inquiry to the typhoid bacillus is, therefore, as I look at it, to ignore the largest part of the question.

Until the bacteriologists add to their knowledge, as they will do some day, so that they can account for the rest of the sickness and death which seems clearly to be caused by polluted water, it will hardly do for them to say that because they have not traced the connection in every step between the sewage of Chicago and the health of the people of St. Louis there is no connection.

The best that St. Louis could do under the circumstances, in the face of such evidence as was presented, was to challenge the evidence, dispute it, and show its limitations. Considering the number and ability of the engineers and bacteriologists enlisted in this case by Chicago, and the energy displayed in following the case up, perhaps it is not surprising that St. Louis was beaten; and under the circumstances she must make the best of it.

Mr. George C. Whipple: Mr. President and members of the Association:

I suppose there has seldom been presented to a body of scientific experts so difficult a problem as that involved in the Chicago Drainage Canal, to really tell whether or not the sewage of Chicago was going to injure the city of St. Louis through its water supply; yet I have sometimes thought that if all the experts engaged on the case could have been gathered into one room from which the lawyers were shut out, and if we could have talked the thing out as we do in our scientific meetings, we could have settled the question a little closer than we have done, and in less than 13,000 pages of words.

It seems to me that in many ways the two bodies of experts approached the subject from entirely different points of view; for example, experts on the other side—and by the "other side" I mean the Chicago experts—have pointed with pride at their average results based upon hundreds and thousands of observations. These results show average conditions which I think experts on the St. Louis side would be willing to accept. The things that the St. Louis experts were interested in, however, were not so much average conditions as the exceptional conditions, those conditions which would occur perhaps once or twice

every year, or perhaps once in a few years. Throughout the investigation our attention was continually being called by our attorneys to these exceptional cases. It is not worth while knowing what these exceptional cases were.

Furthermore, in all this legal work we find that lawyers like to prove their case in an entirely different way from what scientific men do. They think it necessary not only to prove what they want to show, but also necessary to prove that they have proved it; for instance, in one of the parts of the investigation in which I was personally concerned it was desired by the attorneys to show the simple fact that water from the Chicago canal got into the water supply of St. Louis. This, of course, is a fundamental proposition; but they wanted to prove it, and the only way in which they asked me to take the matter up was in connection with microscopic organisms. It was thought that here was something tangible, something concrete which could perhaps be chased down from Chicago to St. Louis; whereas we could not tell the difference in chlorines or in ammonias. We might through some particular organism find that the water from Lake Michigan and from the Chicago sewage actually entered the water pipes of the St. Louis water works. We made a number of examinations of the water of Lake Michigan and of the drainage canal, and of the streams through which it flowed to St. Louis, also of the Mississippi River above the point where the Chicago drainage canal water would enter, also of the Missouri River, and a great many of the smaller tributary streams in Illinois. The result of it all was to show that there was at a certain time in the water of Lake Michigan a certain organism which could be identified and which we could trace down through the streams into the water of St. Louis. That point at least seemed to be more or less direct evidence. That did not, of course, prove that typhoid fever, or some other germ was going to be carried along with the water to St. Louis; but it did seem to show that water from Lake Michigan actually got down and got into the water pipes of St. Louis at certain times. Perhaps in writing out the discussion of this topic I will expand a little more upon the nature of the work that was done in that connection.

There was just one other topic I might refer to here, for the hour is late; and that is, in regard to the experiments which

have been made at various times on the longevity of the typhoid bacillus. I do not think laboratory experiments can be directly applied to natural conditions, yet I do think that they have some degree of application. I do not think that they have always been correctly applied; for instance, in experiments it has been found that many typhoid fever germs die out rapidly at first, then they die more slowly, then more slowly still, until finally there is a small number, as referred to by Mr. Fuller, which apparently are very hardy and live for a long time. We find that in almost every way in which we attempt to kill the typhoid fever germ in our experimental work, whether it be by change of temperature, by sterilization, or in various other ways, there seems to be always a certain small amount of them that live. Now we are very apt to overlook that small amount, and I believe in a case like this one that it is that very small and almost immeasurable amount of typhoid fever which is to be feared.

Mr. Elbert E. Lockridge, Quincy, Mass.: Mr. President and members of the Association:

This is the first I knew I was to talk on this subject. I will take up a little of the work which I did in connection with the case at the time the evidence was completed, the direct evidence for the State of Missouri.

A number of the cases of typhoid were substantially as taken from the printed reports of the city of St. Louis. Those reports were challenged by the Chicago attorneys. The figures were said to have been changed by reason of the Vidal test, which was brought to play in the new register at the time the canal was opened. It was claimed that the malarial, typho-malarial, congestive, enteric fevers, and a half dozen others which were included in one group in the report, had since 1900 been thrown into the typhoid column, and that this was the cause of the increased number rather than a direct increase in the number of typhoid fever deaths in the city.

It was rather late in the day when I began the investigation, which was all put in rapidly. I found on going over the mortuary records of the city of St. Louis that not only had the number of typhoid cases increased, but that this very group composed of the various congestive, typhl-malarial, malarial, enteric and several other fevers which were reported in one

column in the printed report had also slightly increased, and in one case decreased; the increase being very largely in those ages which are most directly affected by typhoid fever; that is to say, in the ages from 15 to 50 the increase was enormous. Further than that, the intermittent and remittent fevers had largely decreased, although the general group had increased; the cause of this decrease being that there had been an epidemic during the early years of children under five, and that this did not occur later.

I then took up the distribution of the city of St. Louis as divided into seven sanitary districts, which follow the ward lines, several wards, however, being included in each district. In these seven sanitary districts the typhoid fever rate was proportioned almost exactly to the number of taps on the city water mains in those districts, and in the two districts where that did not first appear to be the case, both having a larger population, but a considerable well supply, they were not represented by typhoid fever deaths in a direct ratio with the population, but in proportion represented by the ratio of taps to the entire supply.

One other feature was brought in which in the minds of a great many seemed to have confused the situation. St. Louis had a high typhoid death rate due to the presence of the outflow of one of their sewers above their intake. This was gradually changed in varying amount till about four years before the opening of the canal, when the last of it was turned aside, and there was a drop from a high death rate to a death rate averaging about 18 or 20 per 100,000 from typhoid fever. This continued during the four years prior to the canal, suddenly jumping to the old figure in 1900.

I next looked at the matter of when those deaths occurred, and I found that the variation through the year, the disturbance through the year, which in a normal city is higher during the fall, was partially reversed and that the large increase had peculiarly enough followed the time of the higher water of the Illinois valley.

This was all put in in the rebuttal, and not in the direct evidence, and was brought to their attention very late in the case.

It has always seemed to me that the best way to know what a certain water supply is doing is to study the typhoid death rate in connection with the users of that water; and it has seemed to me that the keynote of this case lay in the ascertainment of when and where the typhoid occurred in the city.

PROF. C. E. A. WINSLOW: I think all who have listened to this interesting discussion will be glad to know that an abstract of the testimony has been prepared by Mr. Leighton, Chief Hydrographer of the Geological Survey, who addressed us yesterday. It is a tremendous task, but it has been done, and an abstract covering the main points in all the testimony is now in press and will be distributed as one of the Bulletins of the Geological Survey. That should be ready within a few weeks and can then be obtained by applying to the Geological Survey.

EXPERIMENTS ON LONGEVITY OF TYPHOID ORGANISM IN WATER AND SEWAGE.

(Abstracted by H. L. Russell from papers by Jordan, Russell and Zeit, also by Russell and Fuller.)

In connection with the symposium to be given on the Chicago Drainage Canal case, at the request of your Secretary, the following synopsis of the experimental work on the longevity of the typhoid bacillus under these conditions is herewith presented. It was the original intention to have this paper prepared jointly by Dr. Jordan and myself, but at the last moment Dr. Jordan was unable to assist in this work. These studies were made independently but simultaneously by Professors E. O. Jordan, F. R. Zeit and myself. Prof. Zeit had charge of the work on Lake Michigan and Chicago River waters, Prof. Jordan upon the waters in the Drainage Canal, and the tests on Illinois River were under the writer. The laboratory work in the first two cases was carried out at the Northwestern University and the University of Chicago, respectively; that on the Illinois River at the Biological Laboratory of the Bradley Polytechnic Institute, at Peoria, Ill., while the confirmatory culture work was made at the University of Wisconsin.

In this work, it was of the utmost importance to ascertain as accurately as possible how long the typhoid bacillus would be able to live in the environment to which it would be exposed in passing from the sewage-laden Chicago River, through the Drainage Canal and into the waters of the Illinois River. The experimental data which have been previously accumulated on the longevity of this organism show a marked variation ranging from a few days, to several weeks. This wide variation made it impossible to use these conclusions with any degree of certainty, and the variable conditions under which such experiments have been conducted made it probable that the variations noted were more likely due to the effect of surrounding conditions rather than the actual differences in the vitality of the typhoid organism itself.

In all of the experiments heretofore made, the conditions surrounding the experimental work in the laboratory have always differed materially from those which would obtain where

the typhoid organism was naturally exposed to the waters of a flowing stream.

It was necessary, in these experiments, to simulate as closely as possible the conditions which obtained in nature. To follow these conditions with accuracy, it would, of course, have been preferable to have subjected the typhoid organism to a changing environment, ranging from the highly polluted waters of the Chicago River and Drainage Canal to the Illinois River, in which the processes of spontaneous purification were more or less continually at work. Such conditions, however, were impossible when one takes into consideration the requirements necessary to recover the typhoid bacillus from flowing waters. To simulate the conditions in nature, the following plan was adopted: Cultures of the typhoid organism were simultaneously exposed at certain points in the course of the Drainage channel so as to subject it to the maximum range of environmental conditions. For this purpose five different stations were selected. In Table I. are given the location of these stations, also the distance in miles from Lake Michigan, and the average time of flow:

TABLE NO. I.

No.	STATION	Distance from Lake Michigan	Time of Flow
		MILES	DAYS
1	Lake Michigan (tap supply at 2400 Dearborn St. derived from "Four-Mile Crib")	0	0
2	Chicago River, Ashland Ave	5½	0
3	Head of Drainage Canal, Robey St., Chicago	6	0
4	Mouth of Drainage Canal, Bear Trap Dam, Lockport, Ill	34	2
5	Illinois River, Averyville	125	5-8

EXPOSURE OF TYPHOID ORGANISM.

Heretofore, all work of this kind has been performed in glass containers, but from the work of Ficker, and also Hesse, it is apparent that the use of these containers introduces errors which are considerable, and that the longevity of the typhoid organism is materially enhanced thereby. To overcome this difficulty, it was decided that all experiments be carried on in permeable sacs, which would permit of more or less rapid dialysis; therefore, a state of equilibrium would presumably be pro-

duced between the conditions inside and outside of the limiting sac. For this purpose, the usual celloidin sacs were employed, and also vegetable parchment.

Inasmuch as the value of results obtained depends very largely upon the accuracy of these methods, there is here interpolated the results of a series of studies, made subsequently by H. L. Russell and C. A. Fuller on the technical methods used.* In their studies, in addition to celloidin and parchment, which were employed in the Drainage Canal experiments, sacs made of cellulose shells coated with a thin film of non-nutrient agar, were employed. Comparative tests were made with various solutions, such as sodium chloride, cane sugar and peptone solutions (Witte), in order to determine the relative permeability of these membranes. From these examinations, where such chemical substances of a widely different nature were employed, it was found that the permeability of all three membranes was pronounced. Celloidin, however, was found to be the most permeable. Comparative studies made upon the longevity of the typhoid organism with these three different types of sacs, showed however, so little variation, that any one of the three may be used for work of this kind.

Further tests as to the permeability were made by inoculating with typhoid organisms, sacs filled with raw and sterilized lake water, and immersing the inoculated sacs in running raw water; also a series with sterilized water containing 0.2 per cent. peptone solution. While the content of these sacs and dosage was identical, the results obtained differed greatly. In the peptone series, a very marked growth was observed, both in the case of water bacteria originally present in the raw water, and also the inoculated typhoid. In the running water series, no increase in any of the sacs was observable, and the inoculated typhoid organism died out completely in the course of five days.

These experiments conclusively demonstrate the permeability of such sacs to dilute nutrient solutions, and would seem to show beyond all reasonable doubt that if bacteria die rapidly when imprisoned in such permeable cages, they do not succumb, because of the inability of food substances in the outside en-

* Jour. Inf. Dis. Supp No. 2, Feb., '06.

veloping liquid to pass the limiting membranes of these sacs.

Special experiments were also made to test the germ-proof quality of the sacs. Sterilized sacs filled with sterilized water, and immersed in running water or sewage, remained sterile for periods of a week or more; also sacs inoculated with lake water and immersed in dilute sewage did not reveal the presence of any acid colonies when tested, thus indicating that the colon type, while abundant in the dilute sewage outside, was unable to pass the limiting membrane.

For purposes of seeding, in the experiments detailed, freshly isolated typhoid cultures were used. Three different strains were isolated from the blood, urine and feces of different typhoid patients. Two of these cases terminated fatally, and upon autopsy showed characteristic lesions. These cultures were seeded in varying amounts, depending in some measure upon the native germ-content of the water which was infected. In Table No. 2 are summarized the data on this point.

TABLE NO. 2.

NORMAL BACTERIAL CONTENT OF WATERS TAKEN AT DIFFERENT STATIONS COMPARED WITH TYPHOID SEEDINGS.

STATIONS	Bacteria per Cubic Centimeter	
	Water and Sewage Forms	Typhoid Bacilli Added
Lake Michigan	68- 2,000	540-1,184,000
Chicago River	80,000-1,500,000	500-2,000,000
Drainage Canal (Robey Street)	100,000- 400,000	670- 857,000
Drainage Canal (Lockport)	100,000- 400,000	180- 360,000
Illinois River (Averyville)	1,800- 4,000	540- 20,400

Various methods for the recovery of the typhoid bacillus were used, including the special culture methods of Drigalski-Conradi, Hiss' method, MacConkey, also Horrock's on glucose litmus agar. In the case of the purer Lake Michigan waters, the direct agglutination method of Hagemann, Altschuler's enriching method, and Schuder's chemical precipitation method, were employed.

For the most part, the special culture methods were used for purposes of isolation, and the pure cultures secured from the plates were sub-cultured on various differential media, and finally tested by the agglutination test.

Results. The experiments performed by the three persons engaged in this investigation were carried on independently, so that the results obtained possess a value that is materially greater than would be the case if the work had been done under individual auspices.

In order to observe more closely the effect that different kinds of waters exert on the vitality of typhoid, we have arranged the experimental data on the basis of the waters tested, viz.:

Lake Michigan,
Chicago River,
Chicago Drainage Canal,
Illinois River.

In Prof. Zeit's work, a number of preliminary experiments were made in which the typhoid organism was exposed under the usual laboratory conditions, in glass containers, filled with sterile, as well as raw waters. The detail of these tests will not be presented here, but suffice it to say that the general result shows that the vitality of the typhoid organism when exposed in sterilized waters is much prolonged in comparison with what was found in raw waters.

The results obtained by Zeit and Jordan on Lake Michigan waters are incorporated in Table No. 3.

TABLE No. 3.

No. of Sac	Kind of Sac	Period of Exposure of Typhoid Cultures														
		1 hour	1 day	2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	10 days	11 days	12 days	13 days	14 days
6	Parch	+	+	+	+	+	+	+	0	0	0	0	..	0	..	..
7	"	+	+	+	+	+	0	0	0	0	0	..	0	..	..	..
8	"	+	+	+	+	+	+	+	+	0	0	0	0	0	0	0
10	"	+	..	+	..	..	+	+	+	0	0	0	..	..	..	..
14	Cell	+	+	+	+	+	+	+	+	0	0	0	0	0	0	0
E.O.J.	Parch	..	+	+	+	+	0	0	0	..	..	..	..	..	..	..
E.O.J	Cell	..	+	+	+	+	0	0	0	0	0	..	0	0	0	..

In these experiments the typhoid inoculation varied materially (450,000-2,300,000 organisms per c. c.), but in all cases represented a seeding much heavier than would ever be likely to occur in waters under natural conditions. The lake water

was, of course, relatively low in bacteria (from a few hundred to one thousand per c. c.), so that the typhoid organisms were many times as numerous as the native water organisms.

These foregoing results show a variation in longevity of the typhoid ranging from four to seven days; four out of the seven trials here reported yielded typhoid organisms on either the sixth or seventh day.

A number of exposures were made in the waters of the Chicago River, which is, of course, greatly polluted with sewage and other saprophytic organisms. Determinations made showed from one to two millions bacteria per c. c., and the typhoid seeding added in this case was approximately as much.

Five trials made in parchment or celloidin sacs gave positive typhoid findings in no case later than the third day, although careful examination was extended to the tenth day. In two cases Bacillus typhosus could not be recovered after the second day.

The next group of trials was made on the waters of the Drainage Canal itself, where the pollution, of course, reached its maximum limit. Jordan established two stations, one at Robey Street, at the beginning of the Canal proper; the other at the Beartrap Dam, Lockport, where the Canal empties into the Desplaines River.

Sixteen sacs (all parchment) were exposed at the Robey Street station, and 12 at Lockport. In a number of cases, the bacterial examination of these sacs was not begun until after a lapse of three or four days, the early death of the inoculated typhoid being quite unexpected. This accounts for the lack of data during the earlier part of the tests.

The typhoid inoculation ranged through wide limits (500 to 15,000 bacteria per c. c.), while in some of the later experiments, as many as 857,000 organisms per c. c. were noted.

In the following table No. 4 are summarized the results obtained in the tests made by Dr. Jordan at both Robey Street and Lockport:

Table No. 4.

Summary of Results Obtained in Waters of Drainage Canal. Robey Street.

No. of Sac	Period of Exposure of Typhoid Cultures													
	1 hour	20 hours	28 hours	2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	10 days	11 days	12 days
P_1	+	+	+	+	0	0	0	0	0	0	..	..	..	..
P_2	..	..	..	..	0	0	0	..	0	0	0	+	..	..
N_1	..	+	+	+	0	0	0	0	0	0	0	..	..	..
N_2	..	..	..	..	..	0	0	0	..	..	0	0	..	..
F_1	..	..	..	..	..	0	0	0	..	..	..	..	..	..
F_2	..	..	..	..	..	..	..	..	0	..	..	..	0	0
G_1	..	..	..	0	..	..	..	..	..	..	..	..	..	..
G_2	..	..	..	..	..	..	..	..	0	..	..	..	..	..
H_1	..	..	..	..	..	0	..	0	0	..	..	..	..	..
H_2	..	..	..	..	..	..	..	..	..	..	..	..	0	0
I_1	..	..	..	0	..	0	..	0	..	..	..	..	..	..
R_1	..	..	..	0	..	..	..	..	..	..	..	..	..	..
R_2	..	..	..	..	0	..	0	..	..	..	..	..	..	..
S_1	..	..	..	0	0	..	0	..	..	..	..	..	..	..

Summary of Results Obtained in Waters of Drainage Canal. Lockport.

No. of Sac	Period of Exposure of Typhoid Cultures													
	1 hour	20 hours	28 hours	2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	10 days	11 days	12 days
O_1	+	0	..	0	0	..	0	..	0	..	..	..	..	..
O_2	..	..	..	0	..	..	0	..	0	..	..	0	..	..
B_1	..	0	..	..	..	..	0	..	..	..	..	..	..	..
B_2	..	..	..	..	0	..	..	..	0	..	0	..	..	..
C_1	..	0	..	0	..	..	0	..	0	..	0	..	..	..
C_2	..	..	..	..	0	..	0	..	..	..	..	..	..	..
D_1	..	0	..	0	0	..	..	..	0	..	..	..	..	..
L_1	..	..	..	..	0	..	0	0		0	..	0	..	..
L_2	..	..	..	..	0	..	0	..		..	..	..	..	..
L_3	..	..	..	..	..	..	0	..		..	..	..	..	..
M_1	..	..	..	..	0	..	..	..	..	..	..	..	..	..
M_2	..	..	..	..	..	..	0	..	..	..	..	..	..	..

In all, 1,658 colonies were examined from the Robey Street cultures, of which 184 were found to be typhoid. Of the 1,166 cultures taken after two days, only three typhoids were found. At Lockport 992 colonies were tested with 63 positive typhoid findings.

In this connection, a test was also made at Robey Street with

an organism of the paratyphoid type. This germ was readily recovered, although in continually decreasing numbers for a period of three days, when no trace could be found, although examinations were continued for eight days.

These results are in striking agreement with those of Zeit on the Chicago River, and leave no doubt but that the decline in longevity of the inoculated typhoid was much more rapid in highly polluted waters, like those of the river and the canal, than those of Lake Michigan.

In order to simulate the conditions of exposure that would obtain in the Illinois River, where the typhoid organism found its way into the sewage of the City of Chicago, down the Drainage Canal, and then into this river, exposures were made in the waters of this stream at Averyville, near Peoria, 125 miles distant from Lake Michigan. In this distance, the river had undergone a process of spontaneous purification by virtue of the operation of various factors, which had reduced the germ content from the high numbers found in the Chicago River and the Drainage Canal to 1,800-4,000 per c. c.

Fourteen parchment sacs were used in these tests, the results of which showed that the inoculated typhoid was not recovered with but one exception after the third day, and in most cases, not later than the second day, as is indicated in subjoined table No. 5.

Table No. 5.

Summary of Results Obtained in Illinois River. Averyville.

No. of Sac	Period of Exposure of Typhoid Cultures											
	1 day	2 days	3 days	4 days	5 days	6 days	7 days	9 days	10 days	12 days	14 days	16 days
1	+		0		0				0			
2				0								
3						0						
4				0	0		0					
5	0	+			0	0	0		0	0		
6	+	+									0	
7		0	0							0	0	0
8						0			0	0	0	0
9				0			0		0	0		
10	+		+		0		0		0			
12	+	+			0					0		
13							0	0		0		
14	+						0					
15	+	+			0			+		0		

The results obtained in this complete series are in striking harmony with each other. Organisms exposed to the relatively pure waters of Lake Michigan show a longevity measured by approximately a week's duration. In the highly polluted waters of the Chicago River and Drainage Canal, this organism was only recovered for a period of two or three days, and in the waters of the Illinois River, which had been previously contaminated by the introduction of this load of sewage, the results were practically similar.

From these results, which, it must be remembered, were secured by different observers, under materially different conditions, it would appear that the longevity of the typhoid bacillus was materially reduced in the presence of sewage.

Second Series.—During the past year, further experiments have been made by Russell and Fuller* on this same question. The tentative conclusions drawn as a result of the Drainage Canal work have been tested out on other waters and under other conditions. The experimental methods have been broadened by the introduction of permeable sacs made of agar films, in addition to celloidin and parchment. In this

* For full details see Journ Inf Diseases, Supp No. 2, Feb., '05.

work, tests were made on typhoid-inoculated sacs filled with lake water or sewage and immersed in flowing currents of either kind. A synopsis of the result of these experiments is presented herewith:

TABLE No. 6.

TYPHOID-INOCULATED SACS FILLED WITH LAKE MENDOTA WATER AND IMMERSED IN FLOWING LAKE WATER.

No. of Sac	DAYS															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	+	..	+	+	+	+	+	+	..	0	0	0	0	0	..	..
2	+	..	+	+	+	+	+	+	+	0	0	..	0	..	..	0
3	+	..	+	+	+	+	..	..	+	..	..	..	..	..	..	..
4	+	..	+	+	+	..	+	+	+	+1	+1	..	0	..	..	..
5	..	..	..	+	0	..	+	..	+	..	..	..	0	..	..	..
6	..	..	..	+	0	..	0	..	+1	..	..	..	0	..	..	..
7	+	0	+	+	+	..	+	..	+1	..	0	0	0	..	..	..
8	+	+	+	0	+	..	+	..	0	..	0	0	..	..	..	..
9	+	+	+	+	0	..	+1	..	0	..	0	0	..	..	..	..
10	+	..	+	..	+	..	0	0	+	..	+	..	..	..	..	..
11	+	..	+	..	+	..	0	+	+	..	+	..	..	..	..	..

Note: When x sign is followed by the figure 1, it signifies that only a single typhoid colony was found.

These experiments included four different trials, and they thoroughly confirm the data secured on Lake Michigan waters. While in some cases, the inoculated typhoid persisted for ten days, by far the larger proportion of the organisms inoculated disappeared in the course of seven days.

As the previous tests had indicated a reduced longevity of the typhoid organisms where the exposure was made in sewage, it was deemed advisable to further test this point. For this purpose, five sacs were tested in two different experiments. In all these trials, the typhoid content (which initially varied from 1,500,000-10,000,000 per c. c.) declined very rapidly, and had practically disappeared by the third day. Scattering typhoid colonies were found as late as the fifth day. These results harmonize very satisfactorily with those obtained in the Drainage Canal work, and would seem to be sufficiently numerous to warrant the conclusion that the vitality of this pathogenic organism is profoundly affected by the presence of the saphrophytic sewage flora.

A determination of the factors which are responsible for this decrease in vitality remains another question. Russell and Fuller have studied the influence of diffusible by-products of sewage activity by exposing the typhoid organism in lake water-filled sacs, and immersing same in a stream of flowing sewage. Three different sets of trials were made with thirteen sacs, and the results obtained showed a considerable degree of variation in longevity, varying from seven to eleven days.

In general, the results secured in these trials corresponded quite closely with those of the earlier experiments, in which the lake water-filled sacs were exposed to flowing water. The character of the flowing medium did not seem to exert such a strong influence, as did the liquid in which the typhoid organism itself was suspended. This would seem to indicate that the diffusible products of sewage activity did not exercise as deleterious an influence on the typhoid organism as did the organisms themselves directly. The exact causes that are operative in this antagonism are still under further consideration.

COPPER SULPHATE RESULTS.

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So much has been written of late regarding the action of copper sulphate on the algae and bacteria that I have some hesitation in presenting the results of some treatments with which I am familiar.

The recital of facts which may be of interest and value to the general public is my apology for this paper.

At Elmira, N. Y., an impounding reservoir which was constructed in 1870, (at which time the timber and surface soil were removed), has, owing to algae growths, given trouble at all seasons.

This reservoir was treated with copper sulphate June 25th, 1904.

The copper sulphate was applied at the rate of 1⅓ parts per 1,000,000 parts of water.

Before treatment the water had a strong "fishy" odor and taste.

The principal growths were Anabaena and Asterionella. The Anabaena disappeared 36 hours after the treatment, and the Asterionella 84 hours after the treatment.

Examination of the water from reservoir at Elmira, N. Y., before and after the copper sulphate treatment:

	Before	36 hours after.	84 hours after.	108 hours after.
Odor	fishy	slight	very slight	very slight
Color	25.	25.	22.	22.
Turbidity	57.	35.	28.	28.
Alkalinity	17.	17.	17.	17.
Bacteria per c. c...	315.	42.	25.	18.
B-Coli	present	absent	absent	absent

Before treatment, five samples of 1 c. c. each were examined for B-Coli-communis; two gave positive presumptive results; 36 hours after treatment this bacillus could not be found.

The water before being delivered to consumers is filtered by Jewel Subsidence Gravity Filters. It was found that after the water had been treated with copper sulphate, the period between washings was increased at least three hours, while the wash water was reduced from 2.3% to 1.9%.

The temperature of the water at the time of treatment was 12° C.

Immediately after treating the water, in the shallow parts of the reservoir the "pollywogs" began coming to the surface in large numbers and dying in about one hour.

The fish did not begin to die until about five hours after the treatment had been completed.

The effect upon the animal life was as follows: Numerous "pollywogs" killed, but no frogs; numerous small black bass and two large ones killed; ten large "bullheads" were killed but no small ones; numerous small "sunfish" were killed, but no large ones.

The reservoir has a drainage area of about 4½ sq. mi., covers 38 acres and has a capacity of 113,000,000 gallons, the supply being springs and a small stream, Hoffman Creek.

At the time of this treatment the reservoir contained about 90,000,000 gallons of water, which was treated in less than eight hours, by two men using one boat.

The copper sulphate cost about 57 cts. per 1,000,000 gallons of water treated.

The water remained free from odor and taste for about 16 months, or to October 16th, 1905. At this time however, owing to a renewal of the offensive odor and taste, it was necessary to discontinue the use of the water.

The second treatment was made November 3rd, 1905, at which time Synedra, Asterionella, Anabaena and Volvox were present in large numbers.

About 90,000,000 gallons of water were treated at this time, the dose being 1 part copper sulphate to 2,500,000 parts of water.

At the time of treatment the temperature of the air was 1° C., while that of the water was 7° C.

No odor or taste could be detected in the water six days after the treatment.

It required the services of one man five hours for this treatment, and the total average cost was 19 cts. per 1,000,000 gallons of water.

EXAMINATION OF WATER FROM RESERVOIR AT ELMIRA, N. Y., BEFORE AND AFTER THE COPPER SULPHATE TREATMENT:

	Before	6 days after.	27 days after.	5 months after.
Odor	fishy	none	none	none
Color	30.	16.	15.	25.
Turbidity	20.	8.	8.	68.
Alkalinity	46.	44.	44.	20.
Bacteria per c. c.	560.	130,000.	215,000.	4,150.
B. Coli-communis	2 out 5.	2 out 5.	2 out 5.	0 out 5.

Apparently this treatment did not destroy B. Coli-communis, while the total bacterial contents greatly increased.

No fish were killed.

An examination of this water five months after this treatment did not show any objectionable organisms.

The water supply of Middletown, N. Y., is obtained from three impounding reservoirs, Monhagen, Highland and Shawangunk.

From a sanitary standpoint the quality of these waters is good. The drainage area is owned or controlled by the water department.

The water is filtered before being delivered to consumers.

The filter plant consists of four pressure and four gravity filters of the Continental type, each set having a capacity of 2,000,000 gallons per day.

The water from Highland reservoir passes directly through the pressure filters. The water from Shawangunk reservoir discharges into Monhegan reservoir. These waters pass through the gravity filters before reaching the consumer.

In recent years during warm weather considerable trouble has been experienced by algae growths; not only by the odor which they produce, but also by the rapid "clogging" of the filters. At times the filters would require washing at intervals of from three to five hours.

Monhagen reservoir was constructed in 1867, has a drainage area of 300 acres, surface area of 68 acres and a capacity of 296,000,000 gallons.

This reservoir contained 250,000,000 gallons of water which were treated with copper sulphate at the rate of 1 part to 3,333,000 parts of water.

The labor required for this treatment was the services of three men for 4 hours and 40 minutes each; three boats were used.

The conditions in this reservoir permitted a very uniform treatment.

No fish were killed although they were present in large numbers.

The examination of the water before and after treatment revealed the following organisms:

	Before.	14 days after.
Synedra	2.	
Nitzschia	4.	1.
Ulothrix	6.	
Closterium	3.	
Oscillaria	6.	
Anabaena	15.	
Leptothrix	2.	
Crenothrix	2.	
Pleuerenomema	1.	
Notholea	2.	
Total per c. c.	43.	1.
Bacteria per c. c.	430.	450.

The odor from this water before treatment was noticeable at a considerable distance from the reservoir.

Portions of this reservoir were covered with a heavy growth of Potamegeton (pond weed). Three days after the copper sulphate treatment this growth began to come to the surtace and was raked off. Upon investigation it appeared to have rotted at the root.

The destruction of the Potamegeton, in this manner, was very desirable, because after its death, which occurs during cold weather, it decomposes and imparts a very distinct yellowish brown color to the water.

Highland reservoir was completed in 1891, has a drainage area of 341 acres, a surface area of 110 acres and a capacity of 560,000,000 gallons.

This resrvoir contained 495,000,00 gallons at the time of treatment; the copper sulphate was applied at an average rate of 1 part to 2,292,000 parts of water.

There are a large number of shallow "coves" around this reservoir the water in which required a stronger treatment, which resulted in the killing of a few fish. The estimated strength of the copper sulphate in these localities was about 1 part to 1,250,000 parts of water.

The services of three men 12 hours each were required for this application.

The organisms found before and after treatment follow:

	Before.	6 days after.
Nitzschia	7.	1.
Protococcus	34.	3.
Oscillaria	5.	
Leptothrix	5.	1.
Microcodon	10.	
Notholca	1.	
R. Vulgaris	1.	
Total per c. c.	73.	5.
Bacteria per c. c.	400.	360.

This reservoir also contained a growth of Potamegeton, which broke off after treatment with copper sulphate, and came to the surface where it was raked off.

Shawangunk reservoir was constructed in 1902 and has a drainage area of 422 acres, a surface area of 101 acres, and a capacity of 434,000,000 gallons.

At the time of the copper sulphate treatment this reservoir contained 350,000,000 gallons; the copper sulphate was applied on the average of 1 part to 2,160,000 parts of water, and required the services of three men 11 hours each.

There is a large quantity of decaying wood in this reservoir, owing to the stumps not being removed before the land was flooded.

It was difficult to treat the water in the vicinity of the stumps, therefore the copper sulphate was applied a little stronger than in other parts of the reservoir; this caused the death of a few fish.

The organisms found in the water before and after the treatment were as follows:

	Before.	10 days after.
Nitzschia	8.	1.
Ulothrix	10.	1.
Protococcus		1.
Oscillaria	14.	
Anabaena	12.	
Leptothrix	9.	2.
Total per c. c.	53.	5.
Bacteria per c. c.	300.	260.

Beneficial results were noticeable 24 hours after the treatments.

The temperature of these waters at the time of treatments was about 13° C.

The greatest trouble with these waters commenced about the middle of August 1904. The copper sulphate was applied the first part of September.

The cost of this treatment, exclusive of examinations and supervision, was at the rate of 18½ cts. per 1,000,000 gallons of water treated.

About nine months after this treatment, or about June 1st, 1905, the algae again began to appear in these waters and copper sulphate was applied by Mr. Irving C. Bull, resident chemist.

At the time of this treatment the temperature of these waters varied from 23° to 25° C.

Monhagen reservoir contained 255,145,000 gallons of water, the copper sulphate was applied at the rate of 1 part to 3,150,000 parts of water, by three men in 4½ hours each.

As in the previous year there was a large quantity of Potamogeton in the west end of the reservoir.

Organisms found in the water before and after treatment:

	Before.	7 days after.
Total algae per c. c.	34.	1.
Bacteria per c. c.	395.	405.

The Anabaena numbered over 50% of the total algae.

No fish were killed.

Highland reservoir contained 451,600,000 gallons of water, and required the services of three men 7½ hours each to apply the copper sulphate at the rate of 1 part to 2,894,000 parts of water.

Organisms found in the water before and after treatment:

	Before.	12 days after.
Total algae per c. c.	52.	4.
Bacteria per c. c.	390.	355.

Protococcus and Oscillaria comprised about 50% of the total algae found.

The heavy growth of algae in several localities required a stronger treatment which resulted in the death of a considerable number of fish, the majority being "catfish" of a good size.

Shawangunk reservoir contained 316,784,000 gallons of water which required the services of three men 8 hours each to apply the copper sulphate at the rate of 1 part to 1,885,000 parts of water.

Organisms found in the water before and after treatment:

	Before.	20 days after.
Total algae per c. c.	44.	4.
Bacteria per c. c.	310.	240.

Anabaena and Oscillaria comprised over 50% of the total algae found.

A few fish were killed, mostly trout.

The cost of the treatment including supervision was 37 cts. per 1,000,000 gallons.

At Norwich, N. Y., there are two reservoirs; the larger one with a capacity of 60,000,000 gallons is used as a settling basin, while the smaller one which has a capacity of 30,000,000 gallons, is used as a distributing reservoir.

The main supply comes from Chenango Lake which is several miles away. The water from Chenango Lake is brought to within about three miles by pipe line, after which it flows in the bed of a stream into the settling reservoir.

The water from the settling reservoir is thoroughly aerated while being discharged into the distributing reservoir.

After leaving the distributing reservoir the water passes through New York Pressure Filters before it is delivered to consumers.

From a sanitary standpoint the quality of the unfiltered water is good.

During the summer of 1904 the water in the distributing reservoir had a strong "fishy" taste; copper sulphate was applied at the rate of 1 part to 4,150,000 parts of water, after which the taste entirely disappeared and no further trouble arose during the season.

Early in June, 1905, a taste was again noticeable in the water from the distributing reservoir, and on June 6th, 1905, copper sulphate was applied at the rate of 1 part to 5,000,000 parts of water.

About July 1st a taste was again noticeable in the water from the distributing reservoir, and upon examination, Anabaena was found in large numbers.

At this time copper sulphate was applied to both reservoirs at the rate of 1 part to 3,000,000 parts of water. Twenty-four hours after this treatment the Anabaena could not be found and the water gave no further trouble during the season.

The last treatment caused the death of a few small fish.

For reasons not necessary to mention, I refrain from giving the name of the city in which the following application of copper sulphate was made.

The supply is pumped from a creek to one of two settling basins. The water is thoroughly aerated before entering the basin.

The creek has a drainage area of about 100 sq. miles.

After sedimentation the water passes through Jewell Subsidence Gravity Filters before it reaches the consumer.

These settling basins are brick lined and have a combined capacity of about 40,000,000 gallons, which permits of from 10 to 14 days' subsidence.

About the middle of May 1905 the water in these basins developed a strong "mouldy" odor and taste. At this time considerable trouble was experienced in operating the filters due to the rapid "clogging" of the beds. This caused the filters to require frequent washings.

Basin No. 1 was filled and allowed to stand; in the meantime the supply for the city was taken from Basin No. 2.

Basin No. 1 contained about 17,000,000 gallons of water

which was treated with copper sulphate at the rate of 1 part to 3,000,000 parts of water.

The services of one man and a boat were required for 35 minutes to apply the copper sulphate.

The Bacillus Coli-communis could not be found in the water 72 hours after the treatment, but the bacterial count increased.

Some of the small fish were killed during the first hour; the larger fish did not show the effect of the copper sulphate until about the fourth hour; some died as late as the sixth day.

Examination of the water before and after treatment:

	Before.	72 hours after.
Navicula viridis	20.	
Fragilaria	40.	20.
Crenothrix	40.	
Anabaena	40.	
Pscillaria	180.	20.
Spirogyra	60.	20.
Branchionus	40.	
Statoblast of Plumatella	40.	
Spongilla	20.	
Total organisms per c. c.	480.	60.
Amorphous matter	120.	20.
Temperature	20 C.	20 C.
Alkalinity	26.	26.
Hardness (soap)	21.95	22.50
Bacteria per c. c.	205.	450.
B. Coli-communis	present	absent
Turbidity	13.	7.

On June 10th 1905, Basin No. 2 was about full of water, therefore the supply was shut off and the filters were supplied from Basin No. 1.

At this time Basin No. 2 contained about 16,500,000 gallons of water and the copper sulphate was applied at the rate of 1 part to 3,000,000 parts of water.

The services of one man and a boat were required for 30 minutes for this treatment.

This treatment did not kill the B. Coli-communis; the only great difference in the quality of these waters was the turbidity.

The small fish began to die about one hour after the treat-

ment, but no large fish died until after ninety-six hours.

The cost of these treatments, exclusive of examinations, was 20 cents per 1,000,000 gallons of water.

Examination of water before and after treatment:

	Before.	48 hours after.
Navicula virdis	80.	10.
Stephanodiscus	20.	
Crenothrix	40.	
Anabaena	120.	30.
Oscillaria	200.	10.
Spirogyra	20.	
Branchionus	20.	
Cyclops	20.	
Total organisms per c. c.	520.	50.
Amorphous matter per c. c.	160.	40.
Temperature	21 C.	21 C.
Turbidity	35.	28.
Alkalinity	22.	22.
Hardness (soap)	22.04	21.86
Bacterial per c. c.	300.	330.
B. Coli-communis	present	present.

Liter samples of the water before and after filtration, and also of the wash water, which contained the coagulated matter, were evaporated and tested by the potassium ferro cyanide method, but no copper could be found.

As these basins are about 20 feet deep and the outlet is near the surface, it is probable that the copper had settled to the lower portions before 24 hours.

In testing for copper the writer has found that the following rapid method is sufficiently accurate for all general purposes.

Make a standard solution of copper sulphate by dissolving 1 gm. copper sulphate in 1,000 c. c. distilled water; 10 c. c. of this solution will contain 1 mg. copper sulphate.

Take a large sample of the water before it is treated with copper sulphate.

Take five samples of 1,000 c. c. each of the untreated water and add the proper amounts of the standard copper sulphate solution so as to have the following mixtures.

1 part of copper sulphate to 1,000,000 parts of water.
1 part of copper sulphate to 2,500,000 parts of water.
1 part of copper sulphate to 5,000,000 parts of water.
1 part of copper sulphate to 7,500,000 parts of water.
1 part of copper sulphate to 10,000,000 parts of water.
1 blank.

Add 15 c. c. acetic acid to each of the above mixtures and also to the blank, and evaporate nearly to dryness in porcelain dishes. When nearly dry, "scrub" the dishes and filter off any suspended matter. Wash the precipitate thoroughly making the total filtrate up to 100 c. c.

Place the filtrates in Nessler's jars and use for standards.

Take a 1,000 c. c. sample of the treated water, add 15 c. c. acetic acid, evaporate, filter and wash the same as for the standards.

After the standards and the unknown are in the Nessler's jars add 2 c. c. potassium ferro cyanide solution (20 gms. K_4FeCy_6 per 1,000 c. c. distilled water) match the unknown color with the standards.

When using this method it is seen that any coloration due to iron will be uniform in the standards and the unknown.

Care should be taken to add the same amount of acetic acid to each sample.

The potassium ferro cyanide should not be added until the standards and unknown are ready for comparison.

If a very accurate determination of the copper is necessary, the method as described in the Standard Methods of Water Analysis of the American Public Health Association should be used.

Before copper sulphate is applied to a water for the extermination of algae, the variety and number of the organisms present should be known. It is also desirable to have some knowledge as to the area and depth of the water, the temperature, turbidity, color, alkalinity, hardness and free carbonic acid, before determining the strength of the dose.

The usual method of applying the copper sulphate to reservoir waters has been to place the salt in bags suspended from a boat.

Considerable time is lost in getting the bags adjusted in order

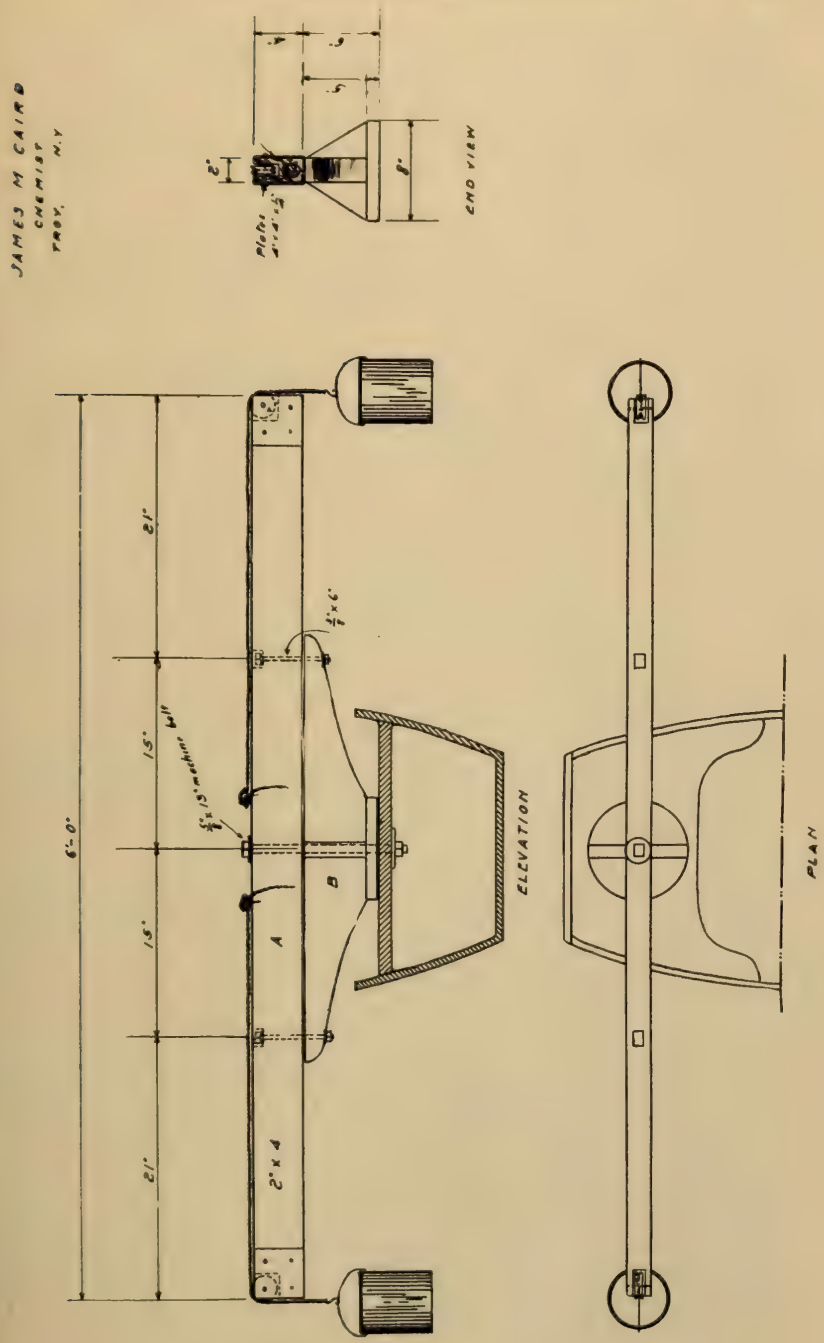
that the desired amount of the chemical may be applied; and when a locality is reached where it is advisable to increase or decrease the amount that is being applied, it becomes necessary to readjust the bags or row the boat faster, or slower as the conditions demand.

The accompanying cut illustrates a contrivance which was designed by the writer to overcome this difficulty.

It is made so that it can be easily attached or detached to the seat of a boat.

The copper sulphate is placed in pails which are made of heavy copper gauze, and lowered to the desired depth in the water.

When the supply of copper sulphate is partially dissolved the arm can be swung over the boat and the pails easily recharged, thereby keeping the dose nearly uniform.


JAMES M CAIRD
CHEMIST
TROY, N.Y
END VIEW
ELEVATION
PLAN
6'-0"
2'-0"
1'-6"
1'-6"
2'-0"
2" x 4"
A
B

Experiments were made to determine the action of copper sulphate on the bacterial contents of Troy, N. Y. (lower service) tap water.

This water comes from the Hudson River, is not filtered and usually contains the B. Coli-communis.

In testing for the B. Coli-communis samples of .1, 1. and 10 c. c. were used, if the reactions for the positive presumptive test was produced in any of the samples examined the result is recorded by a plus sign.

In the following tables the effect of copper sulphate upon the bacterial life in Troy water is well illustrated.

Some of the chemical properties of the water will also be found in the tables.

EXPERIMENT NUMBER ONE.

Time	Control Bacteria	Coli	1-500000 Bacteria	Coli	1-1000000 Bacteria	Coli	1-2500000 Bacteria	Coli	1-5000000 Bacteria	Coli	1-7500000 Bacteria	Coli	1-10000000 Bacteria	Coli
1 hr.	6600	+	300	—	29600	+	7600	+	75600	+	164000	+	160000	+
3 hrs.	13200	+	200	—	29000	—	45000	—	32000	—	58500	+	16900	+
6 hrs.	14000	+	200	—	31000	—	7900	—	51400	—	119000	+	95000	+
24 hrs.	9000	+	700	—	6000	—	396000	+	442000	+	170000	—	53700	+
48 hrs.	5800	+	1000	—	9600	—	94000	—	302000	—	146000	—	453000	—
72 hrs.	3000	+	500	—	2000	—	8700	—	104000	—	19800	—	71500	—

EXPERIMENT NUMBER TWO.

Time	Control Bacteria	Coli	1-500000 Bacteria	Coli	1-1000000 Bacteria	Coli	1-2500000 Bacteria	Coli	1-5000000 Bacteria	Coli	1-7500000 Bacteria	Coli	1-10000000 Bacteria	Coli
1 hr.	16950	+	800	+	108000	+	7000	—	4300	+	4000	—	88700	—
3 hrs.	29200	+	700	—	1700	—	3800	+	4400	+	6900	—	14200	—
6 hrs.	60000	+	6600	—	4900	+	36000	—	52000	+	77000	—	35000	+
24 hrs.	115000	+	6100	—	12800	—	110000	—	167000	+	17000	+	310000	—
48 hrs.	37000	—	6500	—	30000	—	112000	—	134000	—	192000	—	202000	—
72 hrs.	5300	—	8500	—	8400	—	90000	—	116000	—	162000	+	130000	—

EXPERIMENT NUMBER THREE.

Time	Control Bacteria	Coli	1-500000 Bacteria	Coli	1-1000000 Bacteria	Coli	1-2500000 Bacteria	Coli	1-5000000 Bacteria	Coli	1-7500000 Bacteria	Coli	1-10000000 Bacteria	Coli
1 hr.	19700	—	9950	+	3500	—	109000	—	26000	—	65000	—	47000	+
3 hrs.	27000	+	1000	—	57500	—	47000	+	44000	+	136000	—	156000	+
6 hrs.	18900	+	1900	+	4000	+	93000	+	84000	—	122000	—	80000	+
24 hrs.	24000	+	10000	—	64000	—	118000	—	202000	+	200000	+	174000	—
48 hrs.	32000	+	23500	—	55000	—	120000	+	360000	+	297000	—	350000	—
72 hrs.	57000	+	116000	—	328000	+	365000	—	480000	+	310000	+	640000	+

EXPERIMENT ONE.

Turbidity	15.00
Chlorine	2.50
Alkalinity	40.00
Hardness	43.33
Carbonic Acid	6.00
Required Oxygen	3.80
Total Solids	92.00
Loss on Ingnition	30.00

EXPERIMENT TWO

Turbidity	20.00
Chlorine	2.50
Alkalinity	38.00
Hardness	46.59
Carbonic Acid	11.00
Required Oxygen	2.30
Total Solids	95.00
Loss on Ignition	30.00

EXPERIMENT THREE.

Turbidity	25.00
Chlorine	2.00
Alkalinity	38.00
Hardness	51.10
Carbonic Acid	12.00
Required Oxygen	3.50
Total Solids	98.00
Loss on Ignition	.

From the above tables it is seen that the action of copper sulphate upon the bacterial life in Troy water is not altogether satisfactory.

Discussion.

Mr. T. W. Davey: Brother Caird was speaking about treating our reservoir. I will say that I am a believer in copper sulphate, having had experience for three successive years in its use. With regard to all those little things to which scientists give unpronouncable names, inhabitants of water, I cannot tell you anything about them; but I know that, when water becomes bad and in such a condition that it is unwholesome and offensive to smell and taste, a treatment with copper sulphate will remedy that condition. We have had fish die in our reservoir every year, and this has been the case for thirty or forty years. They are principally cat-fish and sun-fish. They die from about the 20th of May to the 20th of June.

A year ago our chemist was in Washington consulting with the authorities there in regard to the fish dying, and the theory of those people is that the fish die because attacked by a parasite or germ. They suggested that it would be a good plan at the beginning of the season when the fish die to try a solution of copper sulphate, and see whether it would have any effect in preventing the death of the fish.

On the 1st of July we treated a reservoir containing 517,000,000 gallons with copper sulphate; but, so far as preventing the death of the fish, it was a failure. Scientists may say that the fish die because of being attacked by a germ or parasite, but experience has taught me that it is not that, for they simply die during the spawning season. Whether it is caused by their fighting among themselves I do not know, but I know that they die.

In the reservoir that was treated last Saturday, which contained at the time 150,000,000 gallons of water, its maximum capacity being 443,000,000 gallons, the reservoir being low at the time, we gave it a treatment of one part to 1,777,000. After treating it on Saturday and completing the treatment at 12:00 o'clock noon, I was up there Sunday morning looking it over, and already you could see a very perceptible difference in the water. There was a very slight green scum over it; but, on taking the water up in your hand, you could see that the algae that were in the water had been precipitated to the bottom. The result of treating the water that had a green scum over it

was that on the second or third day, standing back and looking over it, it had a reddish or brownish cast: during the next three or four days the water cleared off, so that you could stand and look over the water that was green before, and it was all clear, bright and sparkling.

DISINFECTION AS A MEANS OF WATER PURIFICATION.

By George C. Whipple.

There is a growing feeling on the part of some sanitary engineers and chemists that disinfection of water and sewage by the use of chemicals is destined to be a matter of some importance in the future. The idea of adding poisonous chemicals to water for the purpose of improving its quality for drinking purposes has generally been considered as illogical and unsafe, and unfortunately most of the substances which have the power of disinfecting are poisonous to a greater or less extent. An indiscriminate condemnation of the use of chemicals, however, would be unjust. Already the use of alum in connection with mechanical filtration has become well established, and experience in scores of cities has shown that it produces no ill effect on the quality of water. This is also true of lime, soda ash, sulphate of iron, and other chemicals similarly employed. The use of copper sulphate, about which so much has been heard of late, has not been attended with the unfortunate results predicted by some, even though its use has not always accomplished all that was expected of it. Ozone has been employed in a number of instances with satisfactory sanitary results, and even compounds of chlorine have been used with apparent success in a number of places. There is need, therefore, of reconsidering some of the old views regarding the use of disinfectants, and of investigating them carefully to find what are their practical dangers, their merits, and their cost. Almost every sanitary engineer has at one time or another been confronted with conditions where he would have gladly availed himself of the temporary use of a disinfectant for water if he had known of one upon which he could have relied and which could have been used without danger, or even with less danger than that to be feared from infected water.

Recently some of the English chemists have been giving their attention to the study of chlorine, while the use of ozone has been subject to many experimental researches both in Europe and America.

The writer has no comments to offer at this time on the general subject, as he believes existing data are too meager for forming an intelligent opinion. He wishes merely to call attention to the need of a more thorough study of the subject and to describe two water-works in Belgium which he visited recently where chlorine is used as a disinfecting adjunct to filtration, namely, at Ostende and Middelkerke.

Ostende is one of Belgium's most famous seashore resorts. The king has his summer palace there. The population at the height of the season reaches 70,000, but during the winter it is only half as much. The country is flat and the only available water supply sources are the canals and some small sluggish streams. All of the water is more or less brackish. The city supply is taken from the Bruges-Ostende canal a little way above the town. It is turbid (turbidity estimated as 50), slightly brackish to the taste, hard and open to pollution from many sources. The water consumption is said to be about a million gallons per day during the summer.

The system consists of a pumping station, a settling basin, a battery of ten mechanical filters, a disinfecting outfit, a small glass-covered sterilizing chamber, an open pure-water basin, and a standpipe. The mechanical filters are of the Howatson type, which are more or less commonly used in Belgium and France for water-purification, for water-softening, and for sewage treatment. They consist of steel tanks with the usual features of strainers, sand stirrers, etc., and resemble some of the older types of filters sold by filter companies in this country. They are of lighter construction, however, and the devices for controlling the flow, applying the coagulant, etc., are much less perfect than those familiar to American engineers. As a clarifying agent the filter plant at Ostende seemed to be giving local satisfaction using a small amount of alum. It does not pretend to give a high bacterial efficiency.

The novel feature of the Ostende plant is its method of disinfection, which is accomplished by the use of peroxide of chlorine by a method devised by Dr. Maurice Duyk, Chemist to the Minister of Finance and Public Works, Belgium. This substance is made at the works from potassium chlorate and oxalic acid. A mixture of these two salts in crystalline form

is put into earthen trays about a foot in diameter, resembling the saucers used under flower-pots. About four pounds of potassium chlorate and six pounds of oxalic acid constitute a single charge. This is moistened with a little water and put into a chamber kept at a constant temperature of 40° C. This chamber looks like the ordinary incubator used in bacteriological laboratories. It is large enough to hold a dozen or more trays. There is an opening at the back through which the fumes may be withdrawn and a pipe which conveys them to a water tank where they become dissolved. An aspirator is used to suck out the fumes and to prevent them from escaping into the room. Formerly sulphuric acid was used instead of oxalic. The reaction which takes place in the chamber is probably as follows:

$$6\,KClO_3 + 3\,H_2C_2O_4 = 3\,K_2C_2O_4 + 6\,HClO_3$$
Potassium chlorate + oxalic acid = potassium oxalate + chloric acid

$$6\,HClO_3 = 2\,HClO_4 + 2\,Cl_2O_4 + 2\,H_2O$$
Chloric acid = perchloric acid + chlorine tetroxide (chlorine dioxide) + water

$$3\,Cl_2O_4 + 2\,H_2O = 4\,HClO_3 + O_2 + Cl_2$$
Chlorine dioxide + water = chloric acid + oxygen + chlorine

The solution of chlorine dioxide is allowed to trickle into the effluent from the Howatson filter, after which the water passes through the "sterilizing chamber." This is covered with glass and great stress is laid on the action of the sunlight. They do not run the plant during the night except during the height of the season.

The water entering the sterilizing tank has a slight yellowish color and a distinct odor of chlorine—so much so that it is distasteful to drink, but in the tank effluent this is not noticed, although the water tastes brackish. In the open pure water reservoir, which has a capacity of about one day's supply, the water gets a further bleaching and, as pumped to the city, it is absolutely clear and colorless.

The attendant told me that they used 180 parts per million, or about 10 grains per gallon of the combined chemicals.

The plant has been in operation in its present shape for about three years, and is said to have given general satisfaction. The manager said that the bacterial efficiency was ex-

cellent and promised to send me a report stating the results of tests, but this report has not yet been received.

A number of objections have been raised against this process, which seem to be well founded. It is expensive; the chemicals used are costly compared with alum, soda, etc. The chlorine dioxide gas used is explosive at high temperatures, and it is understood that accidents have already occurred. Chlorine compounds of a somewhat objectionable character remain in the water for a considerable time after treatment. The chlorides are permanently increased. The free carbonic acid is increased if the water is hard, and hydrochloric acid may remain if the water is very soft. The process is not one to be commended, but is interesting as showing the limits to which chemical treatment of drinking water may be carried. I could not learn that the use of the water thus treated had any effect on the health of the community.

At Middelkerke (permanent population 2,000; summer population 12,000), another seashore resort, a few miles west of Ostende, the public water supply is also disinfected with a chlorine compound. This is the so-called Ferrochlore process, also devised by Dr. Duyk. It is used in conjunction with a Howatson filter. Ferrochlore is the popular name given to the product obtained by mixing solutions of ferric chloride and chloride of lime. The reaction results in the formation of hypochlorous acid and ferric oxide—the one a disinfectant, the other a coagulant. The reactions which occur may be represented by the following equations:

$$\begin{array}{ccccccc} Fe_2Cl_6 & + & 3\,CaO_2Cl_2 & + & 3\,H_2O & = & 3\,CaCl_2 \\ \text{Ferric chloride} & + & \text{calcium hypochlorate} & + & \text{water} & = & \text{calcium chloride} \\ & + & Fe_2O_3 & + & 6\,HClO & & \\ & + & \text{ferric oxide} & + & \text{hypochlorous acid} & & \end{array}$$

The hypochlorous acid thus formed is fairly stable in dilute solutions, but gradually changes to hydrochloric acid and oxygen, thus:

$$\begin{array}{ccccc} 2\,HClO & = & 2\,HCl & + & O_2 \\ \text{Hypochlorous acid} & = & \text{Hydrochloric acid} & + & \text{oxygen} \end{array}$$

Actually the reaction is probably much more complicated than this, but it is hardly worth while to speculate on the various reactions which might occur with waters of different

character. The main feature of the reaction is the joint production of a coagulant and a disinfectant.

At Middelkerke the process is carried on as follows: The water supply is taken partly from wells and partly from the Plasschendaele-Nieuport canal. The latter is used as an auxiliary supply during the summer when the population is increased. The canal water is filtered through Howatson filters, but ferrochlore is used as the coagulant instead of alum. The capacity of the plant is said to be about 300,000 gallons per day, but the average summer use from the canal is not much above 100,000 gallons.

The two chemicals, ferric chloride and chloride of lime, are dissolved in separate tanks and are mixed just before they are applied to the raw water at the top of the filters. The period allowed for coagulation is very short, yet the coagulation at the time I saw the plant in operation was very good. The filtered water was clear and bright, tasteless and odorless. The engineer tested the water with a starch-potassium iodide solution to determine the presence of free chlorine. The water on the top of the filter turned dark blue at once, indicating free chlorine, but in the filtered water there was only a trace of the blue color, which, the engineer said, would disappear completely on standing a few hours.

The ferrochlore process was studied experimentally at Middelkerke before it was adopted for the general supply, and afterwards it was tested at Montsouris, Paris. It has been favorably considered by a number of water works engineers on the Continent, but thus far its use has not been extended. Several papers and reports have been written describing the results and giving the results of the experiments which have been made. Among these are:

(1) "Noveau Procede d'assainissement des Eaux," par M. Duyk, Brussels, October, 1902.

(2) "Note sur le Procede au Ferrochlore," par M. Duyk, Technologie Sanitaire, Vol. IX., No. 3, p. 57.

(3) "Procede de Sterilisation des Eaux potables dit Ferrochlore," a report to the French Minister of the Interior, by MM. Ogier and Bonjeau (printed for private distribution).

(4) Reports of Dr. Miquel and M. Albert Levy on the "Sterilisation des Eaux par le ferrochlore procede Duyk et

Systeme Howatson." (Extracts printed for private distribution.)

A few extracts from these reports may be of interest.

The experiments at Middelkerke were carried on from July to October, 1902. The capacity of the experimental plant was 40,000 gallons a day, and the purified water was used as a part of the city's supply. During the trial bacteriological examinations were made by Dr. Henseval, Professor a l'ecole de Peche d'Ostende, of samples collected from the raw and filtered water and from the distribution system of the city. The following were the results obtained:

RESULTS OF BACTERIOLOGICAL EXAMINATIONS AT MIDDELKERKE, 1902

	Number of Bacteria per c.c.					Test for B. coli (+ indicates presence) (0 indicates absence)				
	Aug. 1	Aug. 22	Sept. 22	Sept. 29	Oct. 17	Aug. 11	Aug. 22	Sept. 22	Sept. 29	Oct. 17
Raw Water	12,800	6,800	5,000	1,230	6,500	+	+	+	+	+
Filter Effluent	2,120	150	10	12	11	+	0	0	0	0
Distribution Reservoir	458	18	18	1	1	0	0	0	0	0
Tap in City	56	22	12	18	12	–	0	0	0	0

On the days when these analyses were made the amounts of chemicals used were about 1 grain per gallon of ferric chloride and about 1.2 grains of chloride of lime. This was said to be equivalent to about 5 parts per million of active chlorine.

The following is a typical chemical analysis made during the test:

AVERAGE OF SAMPLES COLLECTED JULY 27, 28, 29, 1902.

(Parts per million.)

	Raw Water.	Filtered Water.
Appearance	Yellowish, turbid.	Clear, colorless.
Odor	Pronounced marshy.	Very slight.
Total Solids	832	772
Loss on ignition	232	128
Fixed Solids	600	644
Permanganate absorbed	25.4	19.0
Nitrogen as alb'min'd ammonia.	1.200	0.500
Nitrogen as free ammonia	2.000	1.100
Chlorine	220	240
Free chlorine	0	sl. trace.

Chemicals Used— (Grains per gallon.)

Chloride of lime 0.9

Ferric chloride 1.2

The Montsouris experiments were carried on in 1903 under the authorization of M. G. Bechman, then Chief Engineer of the Water Works, Paris. During April, May and June tests were made by Dr. Miquel and Dr. Albert Levy for the city,

and during November by MM. Ogier and Bonjeau representing the Comite Consultatif d'Hygiene Publique de France. The capacity of this plant was about 25,000 gallons a day. There were two Howatson filters, 1 metre in diameter and 3.3 metres high, with tanks about them for mixing the chemicals. The published reports give little or no information as to the size of the sand used, the rate of filtration, the amount of wash water, etc.—facts which are necessary to a proper understanding of the operation, but the quantities of chemicals used and the analyses of the water are given with more or less detail. The experiments were made on the water from the Seine and also on the ground water from the Vanne.

The following are some of the results obtained during the November tests:

SEINE WATER.

	Number of Bacteria per c.c.			Test for B. coli in 10 c.c. (+ indicates presence) (O indicates absence)		
	1st Series, Nov. 10.	2d Series. Nov. 13	3d Series, Nov. 17.	1st Series, Nov. 10.	2d Series, Nov. 13.	3d Series, Nov. 17.
Raw Water.....	1,869	1,428	2,120	+	+	+
Filtered Effluent..	1	4	10	O	O	O
Reservoir	1	4	88	O	O	O
Chemicals (Parts per million).						
Chloride of lime..	5	4	3			
Ferric Chloride...	30	20	15			

VANNE WATER.

	Number of Bacteria per c.c.			Test for B. coli in 10 c.c. (+ indicates presence) (O indicates absence)		
	4th Series Nov. 22	5th Series Nov. 25	6th Series Nov. 28	4th Series Nov. 22	5th Series Nov. 25	6th Series Nov. 28
Raw Water.....	260	195	250	+	+	+
Filter Effluent....	0	1	13	O	O	O
Reservoir	0	1	67	O	O	O
Chemicals, (parts per million).						
Chloride of Lime	1	0.75	0.5			
Ferric Chloride...	10	10	8			

CHEMICAL ANALYSES.

	Dose. Chloride of Lime.	Dose. Ferric Chloride.	Test* for free chl'rine.	Chlorides.	Organic matter. Acid sol.	Organic matter. Alka. sol.	Dis. oxy.	Hardness.	Alkalinity.
1902.									
Nov. 10—									
Seine	5	30	0	9.8	4.6	4.2	9.3	210	..
Filt.			+	23.0	2.4	2.0	..	225	..
Res.			0	23.0	1.4	2.0	9.9	210	..
Nov. 13—									
Seine	4	20	0	8.0	3.5	2.8	8.0	230	205
Filt			+	15.0	1.8	1.4	9.0	220	200
Res.			0	17.0	2.4	1.8	9.0	220	200
Nov. 17—									
Seine	3	15	0	8.9	4.6	2.8	9.2	220	..
Filt.			+	13.5	2.2	2.7	8.7	220	..
Res.			0	13.5	2.6	2.1	8.9	220	..
Nov. 22—									
Spring	1	10	0	7.0	0.9	0.4	9.9	220	..
Filt.	1		+	11.5	0.6	0.4	9.4	220	..
Res.			0	11.5	1.0	1.0	9.1	225	..
Nov. 25—									
Spring	0.75	10	0	7.2	0.8	0.8	8.7	230	..
Filt.			+	12.0	0.1	0.6	9.3	230	..
Res.			0	12.0	0.8	0.9	9.0	215	..
Nov. 28—									
Spring	0.5	8	0	6.5	1.0	1.8	8.9	215	230
Filt.			+	9.0	0.8	0.6	8.9	215	220
Res.			0	9.0	0.8	0.5	9.2	230	220

* Said to be delicate to 1 part in 5 million.

The Seine water contained about 9 parts per million of chlorine, and 4 parts of organic matter (permanganate test in acid solution). The Vanne water contained 7 parts of chlorine and less than 1 part of organic matter. Both of these waters were much purer organically than the water at Middelkerke.

On the basis of the above experiments it is seen that 4 parts per million of chloride of lime was sufficient to sterilize the Seine water, and 0.75 part for the Vanne water. It is said that the amounts of chemicals needed for ordinary water supplies varies from 0.1 to 0.8 grain per gallon of chloride of lime and from 0.8 to 5.0 grains of ferric chloride.

One advantage claimed for the use of this process is the rapidity with which the floc is formed, thus doing away with large coagulation basins. One decided objection is the increase in the chlorides in the water; another is the possibility of the persistence of hypochlorous acid in the treated water. Considering efficiency and cost it is difficult to see, from the

data at hand, how this system has any advantage over the older methods of mechanical filtration using alum.

The use of chloride of lime as a disinfecting agent was the subject of an interesting paper given by Dr. Samuel Rideal to the Royal Sanitary Institute in 1905. (On the Sterilization of Effluents, Jour. Royal San. Inst., Vol XXVI., No. 7). Among other things it gave an account of some experiments conducted by him showing the efficiency of this chemical in sterilizing sewage effluents and waters of different quality. It was stated that the amount of available chlorine required to produce a satisfactory degree of sterilization varied with the character of the liquid and was about 1.7 times the oxygen consumed in the five-minute test. Effluents from primary contact beds required 20 parts per million of available chlorine, secondary effluents required 10, and tertiary effluents 2.5 with one hour's exposure. Drinking water (character not stated) required less than 1 part per million. The general conclusion was that an ordinary sewage effluent of good quality required about 5 parts per million of available chlorine to give a practical sterilization.

As the available chlorine in chloride of lime is generally less than 25 per cent. of its weight, the above figures would have to be multiplied by 4, at least, in figuring the cost of the method.

Calcium and sodium hypochlorites have been used in many places for sterilizing sewages and are in very general use as disinfectants. They have even been used for water. After the typhoid fever epidemic at Maidstone, England, the entire distribution system was disinfected with a solution of chloride of lime. The question of the relative advantages of calcium and sodium hypochlorite was discussed at some length a number of years ago in connection with studies of what was called electrozone, or sodium hyposulphite prepared by the electrolysis of salt water. It was practically decided that it was the available chlorine which was the active agent and whether or not the calcium or the sodium salt was used made little difference. The latter has a slight advantage, however, in giving less sediment, thus being somewhat more convenient to use. Chloride of lime used with soda has been suggested.

It seems to be generally accepted that it is the oxygen liberated by the so-called available chlorine which is the real disinfecting and oxidizing agent when chlorine compounds are used. What is needed to be known, therefore, is the amount of nascent oxygen necessary to be used in oxidizing the organic matter in water and to bring about a destruction of bacterial life. This is the same question which must be solved before an intelligent idea can be had of the ozone process. About these matters we are still very ignorant. Until the subject has been more carefully studied than it has been with reference to some of its fundamentals it will be futile to discuss the practical use of any of these methods from the standpoint of cost.

The author had intended to take up the question of the use of ozone as a means of purifying water, but, after a somewhat thorough study of the literature of the subject and after visiting some of the places where ozone has been tried, both in this country and abroad, he is inclined to believe that the time has not yet come for a full discussion of the subject. Much attention has been given to this subject, many processes have been devised for its manufacture, experimental plants have been operated, and in a few cases it has been tried on a practical scale. The general result of all this has been to establish two facts. First, that the use of ozone is of considerable value as a sterilizing and oxidizing agent and may have a field of usefulness as an adjunct to filtration or as applied to clean and colorless waters; second, that up to the present time its cost has been so great that it has not been economically successful.

Of the half-dozen or so plants where ozone has been tried in Europe it is said that only one is in regular use. A second one is used at intervals, and a third is operated occasionally for the benefit of visitors. The others have been abandoned. In all these cases it is understood that the difficulty has been chiefly one of expense.

Any process of this character must necessarily pass through a period of experiment and failure, and it is not at all impossible that in time an economical ozone process may be secured. Meanwhile there is no reason why certain scientific aspects of

the question should not be taken up and brought to a satisfactory conclusion. The most important, perhaps, is the one already mentioned, "how much ozone is necessary to sterilize waters of different kinds, how much to oxidize organic matter, how much to decolorize colored waters, etc." These data could be obtained independent of the process of manufacture.

It might have been interesting to have considered the different methods which have been used for the manufacture of ozone, and some of the ways in which it has been applied to water purification. This seems hardly necessary, however, in view of the publication of the elaborate work by H. de la Coux on "L'Ozone et ses Applications Industrielles." It has been thought best to simply present here a list of the more important articles which have appeared on the subject, and await the results of more exhaustive scientific studies before taking up the subject in extenso.

1891.

Frolich, Dr. O.
"Wassersterilisation durch Ozon" (Trade Circular), Siemens & Halske.—Elektrotechnishe Zeitschrift, XII Jahrgang, 1891.

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Ohlmuller, Dr.
"Ueber die Einwirkung des Ozon auf Bakterien."—Arbeiten aus dem Kaiserlichen Gesundheitsamte. Bd. VIII., 5, 229, 1892.
"De la Sterilization des Eaux par l'Ozone."—Annales de l'Institut Pasteur, 1895, Tome IX S, 673.

Ermengen, Dr. E. van
"De la Sterilisation des Eaux par l'Ozone."—Extrait d'un Rapport presenté a M. le ministre de l'Agriculture, de l'Industrie, etc., de Belgique, le 30 juillet, 1895.

Repin, Dr.
"Sterilisation de l'Eau par l'Ozone."—Rev. Gen. des Sciences, VII., p. 596, 1896.

1898.

Electric Ozone Syndicate, Ltd., London.
"Ozone; Its Production; Its Sanitary and Commercial Applications."—(E. Andreoli's Patents), June, 1898 (Trade Circular).

Ermengen, Dr. E. van.
"Purification of Water by Ozone."—Eng. Record, Vol. XXXIX., p. 104, 1898.

Revue de la Presse.
"L'Epuration des Eaux par l'Ozone, Eysteme Andreoli."—La Technologue Sanitaire, No. 2, p. 45, Aout, 1898.

Ermengem, Dr. E. van.
"Sterilisation des Eaux par l'Ozone."—La Technologie Sanitaire, No. 22, pp. 548, 570, 598, Juin, 1898.

1899.

Soper, Geo. A.
"The Purification of Drinking Water by the Use of Ozone."—Eng. News, Vol. XLII., pp. 250 and 256, 1899.

Calmette, Dr.
"Rapport sur la Sterilisation Industrielle des Eaux Potables par l'Ozone."—Procedes et Appareils de Marmier et Abraham. Annales de l'institut Pasteur, 1899, Tome XIII., S. 344.

Weyl, Dr. Th.
"Ueber die Verwendung von Ozon zur Gewinnung keimfreien Trinkwassers."—Journal fur Gasbeleuchtung und Wasserwersorgung XLII Jahrg. No. 48 & No. 49, 1899.

Weyl, Dr. Th.
"Sterilisation of Water by Ozone."—Centralblatt for Bakteriologie, Vol. 26, p. 15. 1899.

Weston, Robert Spurr.
"The Sterilization of Water by Ozone."—Eng. News, Nov. 23, 1899.

1900.

Wehl, Dr. Th.
"Ozone as a Water Purifier."—Eng. Record, Vol. 41, p. 105, 1900.

Hazen, Allen.
"Relative Values of Ozone and Slow Sand Filtration as a Means of Purifying Water."—(Abstracted from the German, a paper by Dr. Th. Weyl.) Eng. News, Feb. 8, 1900.

Labbe, Dr. D.
"Action Physiologique et Therapeutique de l'Ozone."—Congres International d'Electrologie et de Radiologie Medicales, Paris, 1900.

Kemna, Ad.
"L'Epuration des Eaux par l'Ozone."—La Technologie Sanitaire, No. 11, p. 269, Janvier, 1900.

1901.

Berget, M. A.
Rapport sur la Valuer Industrielle et le Rendement des Ozoneurs Rotatifs.—De M. Otto. Paris, 1901. (Trade Circular.)

Erlwein, Dr. Gg.
"Trinkwasserreinigung durch Ozon nach dem System von Siemens & Halske A.-G."—Journal fur Gasbeleuchtung und Wasservenorgung, XLIV Jahrg. Nr. 30, p. 552, 1901.

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Kemna, Ad.
"Filtrage et Ozonisation pour la Banlieue de Paris."—La Technologie Sanitaire, No. 1, p. 1, et No. 2, p. 25, Aout, 1901.

Peton, M.
"La Purification des Eaux de Consommation par l'Ozone."—La Technologie Sanitaire, No. 11, p. 263, Janvier, 1901.

1902.

Schuder und Proskauer.
"Uber die Abtotung pathogener Bakterien im Wasser mittels Ozon nach dem System Siemens und Halske."—Zeitschrift fur Hygiene und Infektionskran kheiten. Band 41, 1902.

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"Ozon-Wasserwerk Paderborn, System Siemens & Halske, A.-G." —Nach einem Aufsatze von Herrn Wr. Gg. Erlwein in "Gesundheit." XXVII Jahrgang, 1902, Nr. 23. (Trade Circular.)

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"Ozon-Wasserwerk Wiesbaden-Schierstein, System Siemens & Halske."—Sonder durck eines Aufsatzer von Herrn Dr. Gg. Erlwein in "Gesundheit," XXVII, Jahrgang, 1902, Nr. 19. (Trade Circular.)

Hoff, Dr. J. H. van't.
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Olderbourg, R.
"Ozonwasserwerk Wiesbaden-Schierstein nach System Siemens und Halske, von der Elektrochemischen Abteilung der Firma."—Journal fur Gasbeleuchtung und Wasserversorgung. Jahrgang XLV. Heft Nr. 40.

Schindler, R.
"Trinkwasser-Reinigung durch Ozon nach System Siemens und Halske."—Gersundheits-Ingenieur. Jahrgang 25, 1902. Heft. Nr. 5.

Ohlmuller, Dr., und Prall, Dr. Fr.
"Die Behandlung des Trinkwassers mit Ozon."—Arbeiten aus dem Kaiserlichen Gesundheitsamte. Band XVIII, 1902. Heft. 3.

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"Ozon-Wasserwerk Weisbaden-Schierstein nach System Siemens & Halske, A.-G."—Journal fur Gasbeleuchtung und Wasserversorgung. XLV. Jahrg., 1902. Nr. 40.

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"Ozon-Wasserwerk Wiesbaden-Schierstein."—Zeitschieft "Gesundheit." Jahrgang XXVII, 1902; Nr. 19.

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"La Formation de l'Ozone."—La Technologie Sanitaire, No. 13, p. 317. Fevrier, 1902.

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Ramsay, Sir. Wm.
"Report on the Apparatus of the Ozone Industrials Syndicate."—Scientific Report Univ. College, April 30, 1903.

Imbeaux, Dr. Ed.
"Sterilisation de l'Eau par l'Ozone."—(Premieres tentatives et premieres installations.) La Revue Technique, 25 Juin, 1903.

Siemens & Halske, A.-G.
"Uber Trinkwasserreinigung durch Ozon und Ozunwasserwerke."—Sonderabdruck aus dem Journal fur Gasbeleuchtung und Wasserversorgung, Jahrgang, 1903, Nr. 43 u. 44. (Trade Circular.)

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"Les progres recents realises dans l'industrie de l'Ozone."—Memoires et compte rendu des travaux de la Societe Ingenieurs civils de France. Bulletin de Novembre, 1903.

Gray, Arthur W.
"Uber Ozonisierung durch stille elektrische Entladungen in dem Siemens' schen Ozonapparatchen Akademie der Wissenschaften, 1903, XLVI.

Warburg, E.
"Über die Ozonisierung des Sauerstoffs durch stille elektrische Entladungen."—Sitzungsberichten der Koniglich Preussischen Akademie der Wissenschaften. 1903, XLVI.

Friberg, H.
"Uber Trinkwasserreinigung und Ozonwasserwerke."—Zeitschrift "Das Wasser" Jahrgang, 1903, Heft. 19.

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"Weitere Beitrage zur Technek der Ozonwasserwerke."—Gesundheits-Ingenieur, Jahrgang 26, 1903, Nr. 30.

1904.

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"Sterilisation de l'Eau au moyen de l'Ozone."—Bureaux 38, Rue du Louvre, Paris, 1904. (Trade Circular.)
Ogier et Bonjeau.
"Sterilisation des Eaux Potables par l'Ozone."—Procede de la Societe Sanudor Systeme de Frise. (Approuve par le Comite consultatif d'hygiene de France dans la seance du 5 Decembre, 1904.)
Bridge, James Howard.
"The Ozone Treatment of Public Water Supplies."—(Aldine Book Co., New York.) 1904.
De Kinder, J. J.
"Report on the Vosmaer System of Producing Ozone for the Purification of water and other purposes."—System owned by United Water Improvement Co., Philadelphia, 1904. (Trade Circular.)
De la Coux, H.
"L'Ozone et ses Applications Industrielles."—Vve Ch. Dunod, Editeur, 49, Quai des Grands-Augustins, Paris, 1904.
Wasserwerke der Stadt Wiesbaden.
"Mitteilungen uber das Ozon-Werk zur Trinkwasser-Sterilisierung in Schierstein a. Rh."—Februar, 1904.
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"Analyse Bacteriologie d'Eau de Marne. Filtree sur Bassins de Sable. Sterilisee au moyen de l'Ozone (System de Frise).—Faculte de Medecine de Paris. le 8 Mai, 1904. (Trade Circular.)

1905.

Ewell, Dr. Arthur W.
"Ozone for Water Purification."—Eng. Record, Vol. LII, p. 260, 1905.
Gerard, Leon.
"L'Epuration des Eaux Alimentaires par les Procedes Electriques."—La Technologie Sanitaire, No. 20, p. 305, Mai, 1905.
Miquel, Dr.
"Nouvelles Experiences relative a la Sterilisation de L'Eau au moyen de l'Ozone." (Systeme de Frise.)—Direction des Affaires Municipales, Laboratoire de Bacteriologie, le 14, Decembre, 1905. (Trade Circular.)
Gerard, Leon.
"L'Installation d'Epuration Electrique des Eaux a Ginneken (Breda)."—La Technologie Sanitaire, No. 16, Mars, et No. 17, Mai, 1905.
Miquel, Dr.
"Experiences relatives a la Sterilisation de l'Eau au moyen de l'Ozone." (System de Frise.)—Direction des Affaires Municiples. Laboratoire de Bacteriologie, le 8, Avril, 1905. (Trade Circular.)

1906.

Rivas, Dr.
"On Results obtained in Purifying Water by Ozone."—Bacteriological Report of Water Department of the City of Philadelphia, 1906.

Steens, A.
"The Sterilization of Water Ozone."—Eng. Record, Vol. LIII, p. 31, 1906.
Courtmont, Dr. J, et Lacomme, Dr. L.
"Rapport sur la Sterilisation des Eaux par l'Ozone." (System de Frise.)—Faculte de Medecine de Lyon. Laboratoire d'Hygiene, 1906. (Trade Circular.)

The literature on the subject is extremely disappointing in many respects. Reports which state the amount of ozone used do not indicate whether a smaller amount would have been satisfactory. Generally the analyses are given for the raw water and for the water treated with ozone, even when a filter was used in connection with the sterilizing process. The published analyses do not often show the work of the ozone process alone.

Ozone is often applied in excess and the amount used is determined by making analyses of the water after treatment to determine the residual ozone. This gives inaccurate results for the reason that some of the ozone is changed to oxygen without doing any work.

The tests for determining ozone are not always comparable and differences of 25 to 50% may easily be made.

From the somewhat conflicting data at hand the extreme limits of ozone which have been used are 0.3 to 3 parts per million of ozone. Most of the figures lie between 1 and 2 parts per million. The reports do not show any definite relation between the number of bacteria in the untreated water or the amount of organic matter and the quantity of ozone used, and it is very evident that the process has been applied in most cases in a haphazard manner. In a general way the fairly turbid waters and those which contain a large number of bacteria require the most ozone and the following may be taken as approximately indicating the quantities which are necessary under the average conditions of past practice.

	Parts per Million Gallons.
Ground waters	0.5 to 1
Surface waters, filtered to remove suspended matter	0.1 to 2
Surface waters, imperfectly filtered	0.2 to 3
Surface waters, turbid or colored without preliminary filtration	0.3 or more

Discussion.

Mr. Herschel: (by letter) On the very day that Mr. Whipple's paper was read, July 12, there appeared an article in Engineering News on "The Ozone Process for Treating a Part of the Water Supply of Wiesbaden, Germany," which controverts the statement made in the paper, that the ozone plant at Wiesbaden had been abandoned, and also the statement that its operation was inordinately expensive.

As regards the first, it appears that Wiesbaden is supplied from two sources. Whenever possible, it prefers to supply itself from a source which furnishes pure water, that is to say: from one that does not need any further purification, being what might be termed "artificial springs," which yield pure spring water.

But occasionally this pure source of supply fails, or becomes insufficient in quantity, and at such times Wiesbaden is compelled to use water that needs purification. It is this water which is subjected to the ozonizing process, and the abandonment of this process referred to applies only within the times when the impure source of supply is not drawn upon, and when there is no occasion for using any purifying process.

As regards the expense of the process, this is what the manager of the works says about it: "The ozonizing process is rather an expensive one, and is made so principally by the many bacteriological tests which are necessary for the control of the proper working of the plant."

It has not been customary, in discussing the cost of the different processes for purifying water, to include in that cost the bacteriological tests made upon the purified water. These are, in Germany, presumably made compulsory by Government supervision.

At all events, it appears that we have no exact accounts of the cost of the ozonizing process, which can be compared with the costs of other methods of purification, such as filtration and others, in our current literature, as yet.

While I am discussing the paper by Mr. Whipple, it may be well to point out, also, that to apply the term "disinfectant" to a substance as harmless or even beneficent as ozone, would seem to be a rather harsh classification. So far as I am informed, the ozone process is the only process of purifying water, in

which a temporary or intermittent neglect or failure by employees, in conscientiously applying the process, will not make the resultant effluent worse, after it leaves their hands, than it was when they received it. By the application of the ozone process, they may succeed in not purifying the water as much as it should have been purified, but they never could make it worse than they found it; as they are likely to do in the working of all the other purification processes, including filtration.

That my strictures on the term "disinfectant" are warranted, was proved at the Convention by another speaker, who immediately seized on the term "disinfection" to point out, that no attempt should be made to utilize water for drinking purposes, that needed disinfecting.

So that we have this line of argument: The ozone process is classed as a disinfector, and the purification of water that needs disinfecting, should not be attempted.

From the statement of Professor Kinnicutt, it would appear, however, that there is, nevertheless, a fair prospect of the introduction, into the United States, of the method of purifying water for domestic supplies by the use of sedimentation and the ozone process alone, and without the necessity of using any form of filtration in addition, as has been claimed is necessary; and in Europe that method is already in operation.

Dr. W. P. Mason:—This paper by Mr. Whipple is certainly very timely and also very able. I cannot but feel, however, that it is presented somewhat in the spirit of prophecy, covering ground that we shall be forced to take in years to come. The idea of disinfection of water supplies seems to me to belong more to the future than to the present. I very much question if the public at large would be willing to disinfect water to-day. We are scarcely driven that far as yet. The time may come when we shall be compelled to use raw water of such a character that disinfection will be absolutely required; and right in line with that thought comes the question, How polluted must a water be before we reject it as a raw supply? That question can not now be answered. I presume that there is no limit to the amount of pollution that can be borne by a raw water provided that we be driven to grapple with so serious a condition of affairs. Let

me instance a case in point: The Saratoga sewage filter plant is now delivering an effluent which looks like spring water and is used as such by people living near. They drink it. I have the greatest faith in the efficiency of the Saratoga filter plant, but I am not yet willing to drink its effluent. The time may come when we shall be driven to the use of a raw supply as bad as Saratoga sewage, and I believe we shall be able to solve the problem of its purification when that day arrives, but we are not called upon to do it yet. I feel, therefore, that Mr. Whipple's paper deals with possible questions of the future rather than with those presented by the needs of to-day.

Let me say one word with reference to ozone. I entirely agree with the view that it is so expensive that we cannot afford to pay its cost; but in looking over the Vossmeier plant near Amsterdam, Holland, I was very much struck by the fact that not only the color of the water was improved, but, strange to say, the turbidity as well. I saw no reason why the turbidity should be lessened unless it were in part due to the presence of oxidizable material of an organic character.

Mr. Whipple referred to chloride of lime, and touched upon the ozonated oxy-chloride treatment at the same time. This, as you know, was established under patent rights some years ago, and attempts were made to apply it to the water supply at Brewster, where chlorinated sea water was run into the system through perforated gas pipes. The people of New York were not prepared, however, to apply that method to the city supply as a whole.

With reference to the direct use of the halogens, chlorine for instance, I have no experience. I have used bromine for a specific purpose, but that was for disinfecting a reservoir, which hardly comes under the topic covered by the paper. Bromine was chosen in that case because bromine water was easy to make, and the reservoir bottom was sprayed therewith.

I feel that filtration, whether of the mechanical or English form, is capable of doing fully as much for us as we require to-day. It is my belief that the people are not yet ready to disinfect their drinking water, because raw supplies of sufficiently good character are still to be secured.

PROF. KINNICUTT:—I have listened with very great interest to Mr. Whipple's paper, because last year I also studied in Europe the various processes of disinfection that Mr. Whipple has described. I do not quite agree with Dr. Mason that it is entirely a question of the future, for I think at the present time in certain cases there is a use for disinfecting agents. Especially is this true with regard to supplying our armies with pure water. The question of how to supply pure water to armies in the field is one of great importance, as was shown in the late Spanish war and in the war in South Africa. Of course, there are various forms of apparatus for sterilizing water by heat, but these are not very easily carried into the field, and consequently various chemical disinfecting agents, like those described by Mr. Whipple, are now being tested by the English government for the use of the English army on foreign surface.

As regards the purification of water by ozone, I examined last year the various ozone plants both in Holland and in France, and I agree with Mr. Whipple when he says none of them are at the present time commercially successful. Yet, although the expense of the ozone treatment of water is great, I think there is possibly a future for this method of treatment. It is a process that may in the future be used for treatment of water which has been partially purified by mechanical or sand filtration. Undoubtedly, by the use of ozone, one can obtain perfectly sterilized water. This is almost impossible—if not impossible—to obtain by either mechanical or slow sand filtration. Ozonation is merely a question of expense and the great trouble with ozone treatment of water supplies is that it depends, not only upon the amount of ozone used, but upon the amount of concentration; or, in other words, the amount of ozone in the air that we force through the water. It is comparatively easy and not very expensive to obtain a low concentration, that is, to obtain air which contains a small amount of ozone, but this does not produce sterilization. Sterilization depends upon the concentration of the ozone in the air. If we have a concentration of say two and a half milligrams of ozone to the liter of air we can very easily sterilize the water, but to obtain a concentration of two and a half milli-

grams of ozone to one liter of air is about four times as expensive as to obtain one milligram of ozone in one liter of air, and air containing one milligram of ozone to the liter will not perfectly sterilize water. The problem of the sterilization of water by ozone is, therefore, one of concentration; and the problem at the present time is how to procure air containing a large amount of ozone at a cheap price. If that can be done, it seems to me that there is a future for the treatment of water by ozone.

There is one other statement I would like to make—Prof. Mason has referred to removing turbidity by ozone. I have examined all the plants that have been mentioned, and have never seen color or turbidity removed by ozone.

Theoretically, I do not see how it is possible.

PROF. MASON: Do you not know that a little positive information is worth any amount of negative testimony.

PROF. KINNICUTT: If it is positive.

PROF. MASON: I saw the water before and after it passed the ozone plant, and a portion of the turbidity, greatly to my surprise, was removed. Of course, I assume that such turbidity was in part due to organic material. I could not otherwise conceive of its being removed by any ozone process.

MR. MAIGNEN:—The speaker can perhaps throw some light upon the matter in dispute between the two last speakers. He has caught, in the remarks of Professor Mason, the word "outfit." Now, it so happens that a filter is an essential part of an Ozone "outfit;" perhaps this will explain why the ozonized water was clear when the professor saw it!

Ozone has been tried, in Paris, for the purification of water, after filtration through slow sand filters, for 15 years; but so far as the speaker knows, little progress has been made in the way of practical application on a large scale. The system seems to be still in the experimental stage.

When the water to be ozonized contains an appreciable quantity of suspended and dissolved organic matter, ozonization is very expensive, because the ozone is consumed by the organic matter and much of it must be used in order that there may be some left to act upon the bacteria.

The ozonization process is very complicated. The air which

is to be ozonized must first be deprived of moisture by freezing, and afterwards placed under pressure in order to make it absorb ozone in sufficient quantity; and then, it has to be blown through a high column of water. Every one of these factors cost money.

It has been said that the ozone treatment distinguishes between disease producing and non-producing germs. The fact is that, when used in sufficient quantity, ozone, like other chemicals, destroys the adult bacteria (which are easily affected by changes in the environment), but ozone like simple boiling or freezing, does not destroy the vital principle of the spores or spore bearing bacteria.

Some of the advocates of ozonization assert that the spore-bearing bacteria are not pathogenic; this is not by any means proven; a number of spore-bearing bacilli are known to produce disease.

To one like the speaker, who has for years worked with filtration and simple chemical reactions, the treatment of water with ozone appears like using a gold steam hammer to kill a fly.

The slow sand filter plants at South Bethlehem and Lancaster give a bacterial efficiency of 99.5 per cent. He doubts whether the ozone process can do better.

The word "disinfection" was used yesterday in connection with the subject of water purification. Among the so-called "disinfectants" tried may be cited copper, chlorine, and oxalic acid. All these substances are poisonous. They certainly can kill the bacteria, but they also kill the fish and cannot fail to be hurtful to man. Such poisonous materials should not be permitted to be used on water intended for public supplies.

The substances used for water softening—lime and soda—are not poisonous, and they may be used without danger. An excess would render the water unpleasant to drink. It would be refused by the palate. The speaker has found that when lime, soda or alum are used separately on the water, as much as 200 grains of either are required to kill the bacteria; but the water so treated is undrinkable.

Mr. Davis:—I would like to present this matter from water works standpoint, as it has been presented to us through chem-

ists. I do not object to anticipation as Professor Mason does; but I think that we want to lead these men back to the original proposition, which is that there shall be no pollution of the stream; in other words, there shall be nothing put into the streams that we will be forced to take out. The streams are for the beauty of the land, for fish, for cattle, and for the use of man and it is rightful that the streams should be kept pure. It seems to me it is our duty to look forward to keeping them pure instead of permitting them to become so foul that we will be obliged to disinfect them. The streams are shrinking in volume every year, and on the other hand pollution due to the multiplying population occupying their borders is at the same time increasing; so that in a short time the inevitable result will be to produce such filthy conditions that we shrink from contemplating them.

Secretary Diven:—I do not want to advocate sterilization as a means of *purification;* but as a preparation for purification I have found it exceedingly useful; in fact, necessary. I am dealing with a water which contains all the organisms that I can find in Mr. Whipple's book, and a whole lot of others! I would like to have Mr. Whipple down there; I think it would be a paradise for him. He would write three or four more books in a very short time, but I believe that the water without a sterilization process would be impossible to use. We do not rely on sterilization for bacterial results at all. It does have some effect, but it is not relied on. It would be impossible to filter this water without preliminary treatment with copper sulphate. Filtration does not take out the odor caused by algae in the water, that I think we all know; but the sterilization, by use of copper sulphate, does remove it.

Mr. Whipple:—There is just one thing I would like to say in concluding this discussion. I have been very much pleased at the interest which has been manifested in this subject, but I do not wish to be misunderstood. With regard to the use of these new methods I am in some respects more conservative than any of the gentlemen that have spoken; but I think that it does us good sometimes to think outside of the ordinary lines, and these various methods have been talked about a good deal of late. I believe that instead of indiscriminately condemning

the use of disinfectants it would be far better to take up the subject in a scientific way and learn just what can be done and what cannot be done with them. We should then be in a position to form a better opinion as to their usefulness than by by merely talking them over in a haphazard manner.

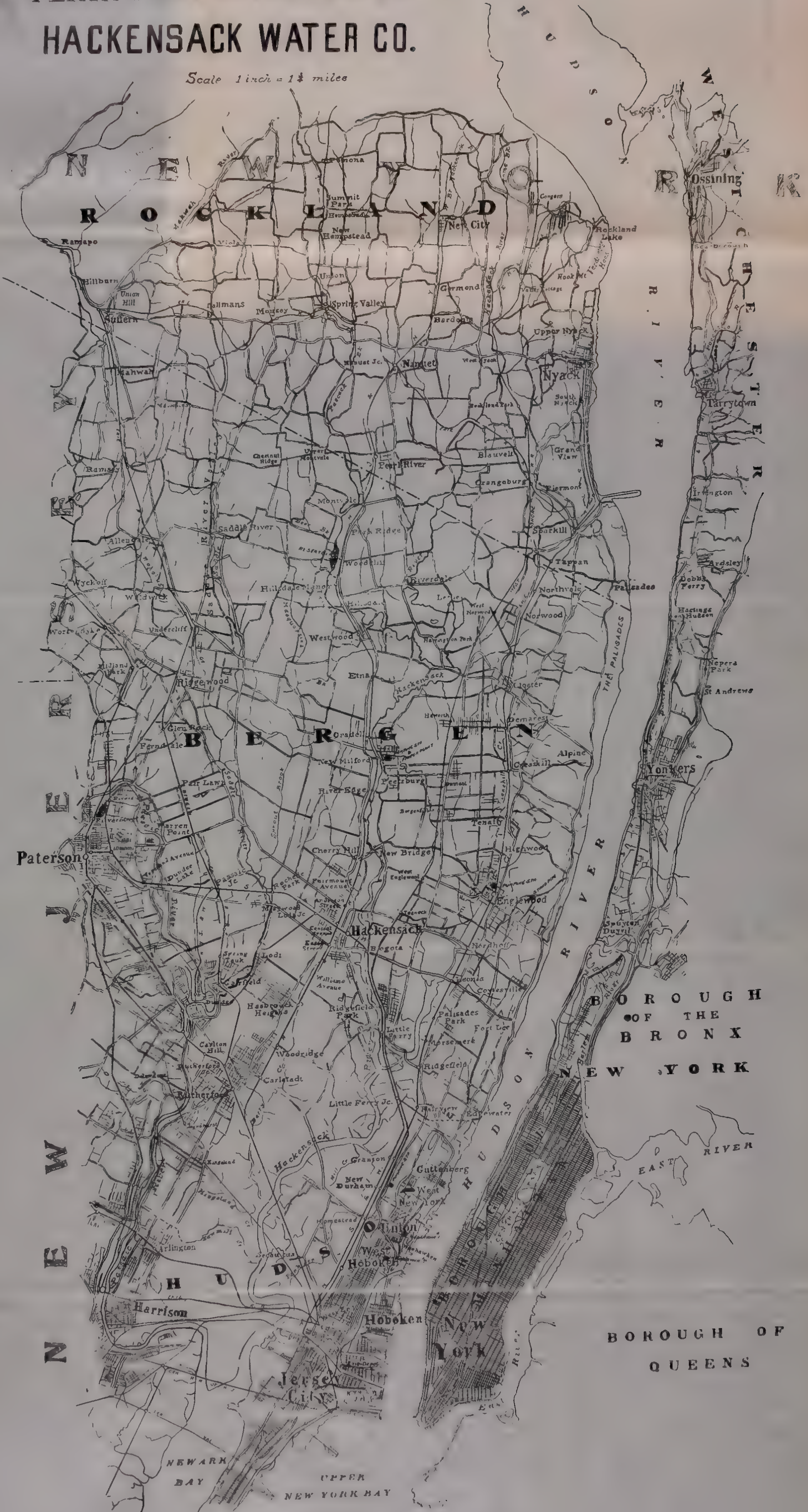
MR. F. L. FULLER:—I would like to endorse every word which Mr. Davis has just spoken. It seemed to me at the other conventions, when we were discussing the pollution of streams, that a little too much allowance was made as to what should be permitted to be turned into streams. We see it everywhere all over the country. I suppose I am more acquainted with New England streams than any other, but we have so many streams in New England which have become exceedingly foul. Different manufacturing wastes are turned into all these streams, and I do not see how we can ever expect to very much improve the quality of the waters in these streams while we allow so much pollution of one kind and another, the effluents from sewage beds, waste from manufacturing establishments, etc., to flow into them. Under these circumstances water in our streams is bound to become worse and worse, and if as it becomes bad more waste is allowed to go into them because they are already foul, they will simply keep on going from bad to worse very fast. I believe further that we should maintain the standard of the water that is to be turned into our streams. I have lately become acquainted with a beautiful stream in Vermont whose waters are perfectly clear, and yet the people there turn sewage into it and seem to think that the stream was made for that especial purpose. Everything is dumped into it, tin cans and all sorts of refuse. The stream is becoming spoiled.

Here in our own State of Massachusetts, also, Blackstone River is becoming little better than a sewer. It seems to me that an association like this should have for one of its legitimate purposes the striving to maintain the purity of our streams.

MR. FRENCH:—This paper is a relation of our experience. While this has been very satisfactory as applied to the Hackensack Water Company's system, I do not pretend to say that it will apply in every case, but only under similar conditions to those prevailing with us.

MAP SHOWING PORTION OF
TERRITORY SUPPLIED BY
HACKENSACK WATER CO.

Scale 1 inch = 1¼ miles



INCREASING THE CAPACITY OF THE HACKENSACK WATER COMPANY'S SYSTEM BY INTRODUCING A RELAY PUMPING STATION, AS COMPARED WITH COST OF BUILDING A NEW FORCE MAIN.

By D. W. French.

The Hackensack Water Company is a private corporation organized and existing under the laws of the State of New Jersey, and operating in the territory located between the Hudson and Passaic Rivers, north from Jersey City.

The Company commenced doing business in 1882, by supplying water to the City of Hoboken, N. J., which at that time was its only customer.

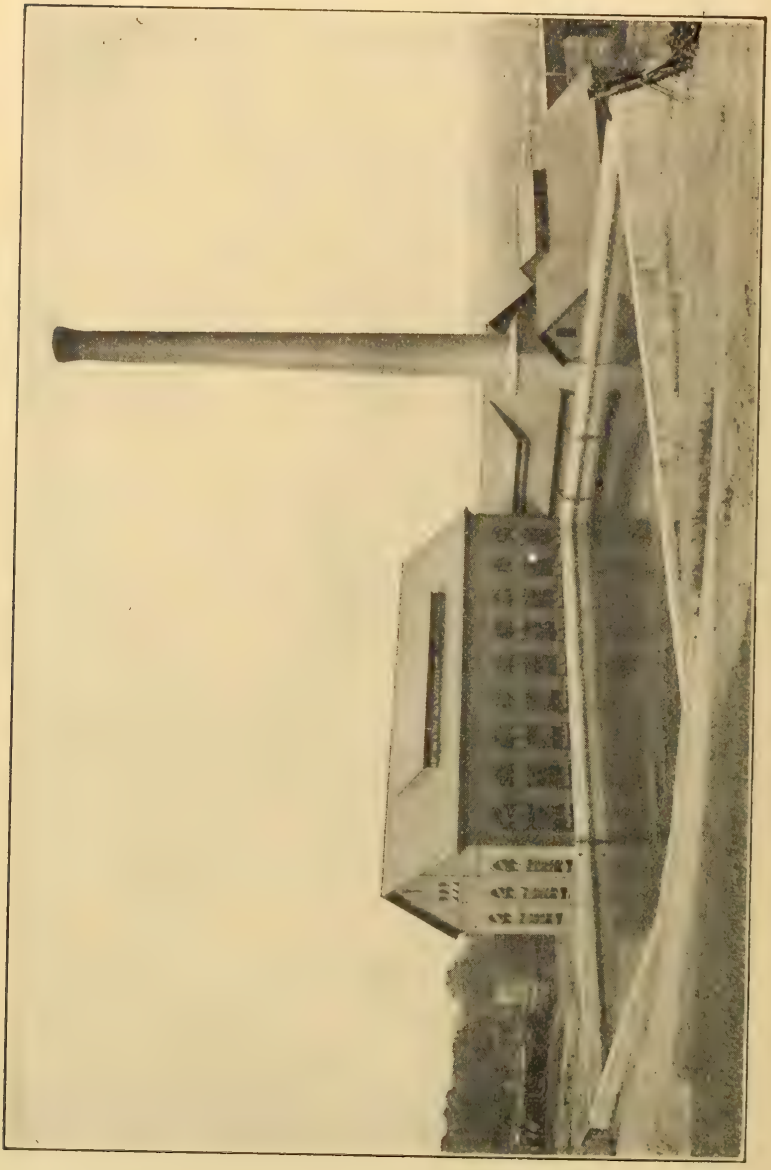
At the present time supply is furnished to forty-one (41) towns and boroughs, including two (2) cities, varying in population from about one to sixty-five thousand, and with a daily consumption of 20,000,000 gallons, ninety per cent. of which is metered.

The entire system is a pumping system with the main station located at New Milford, N. J., at elevation 10 feet above mean high water, and two distributing reservoirs located at Weehawken, N. J., practically fifteen miles south from New Milford, at at elevations of 180 and 194 feet.

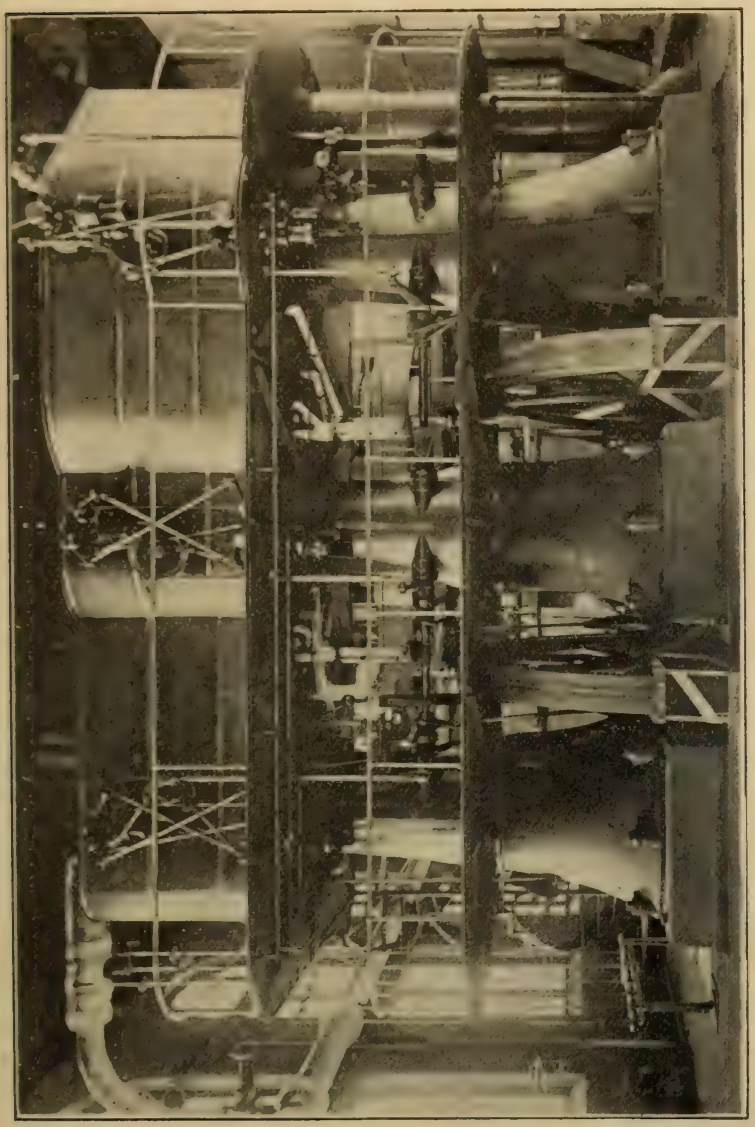
The pumping station and reservoir are united by three mains, a twenty-inch, a twenty-four- inch, and a compound main of thirty and thirty-six-inch, each of which are laid over different routes, and from which many of the small towns obtain direct supply.

About ten miles south from New Milford, at a junction called Ridgefield, the three mains meet and practically parallel each other along a public highway south to the Weehawken reservoirs.

The capacity of the three mains referred to when running at a water pressure at New Milford of 120 pounds per square inch, which corresponds to a velocity in the mains of three feet per second is 20,000,000 gallons.



New Durham Plant, Hackensack Water Co.—Looking Southwest.



New Durham Plant, Hackensack Water Co., 20 Million Gallon Pump.

In the summer of 1903, with our daily consumption steadily exceeding 17,000,000 gallons, and knowing that the route over which a new 42-inch or 48-inch main would be laid, and that to obtain 85,000 feet of such pipe and lay it would require the best part of two years, it was quite evident that some steps should be taken to increase the supply to the reservoirs without much delay.

The disposition of our Board of Directors was to lay a 42-inch main from New Milford to the Weehawken reservoirs, the capacity of which being practically 19,000,000 gallons per day would have about doubled our main carrying capacity, as well as furnishing an additional feeder to different parts of our territory.

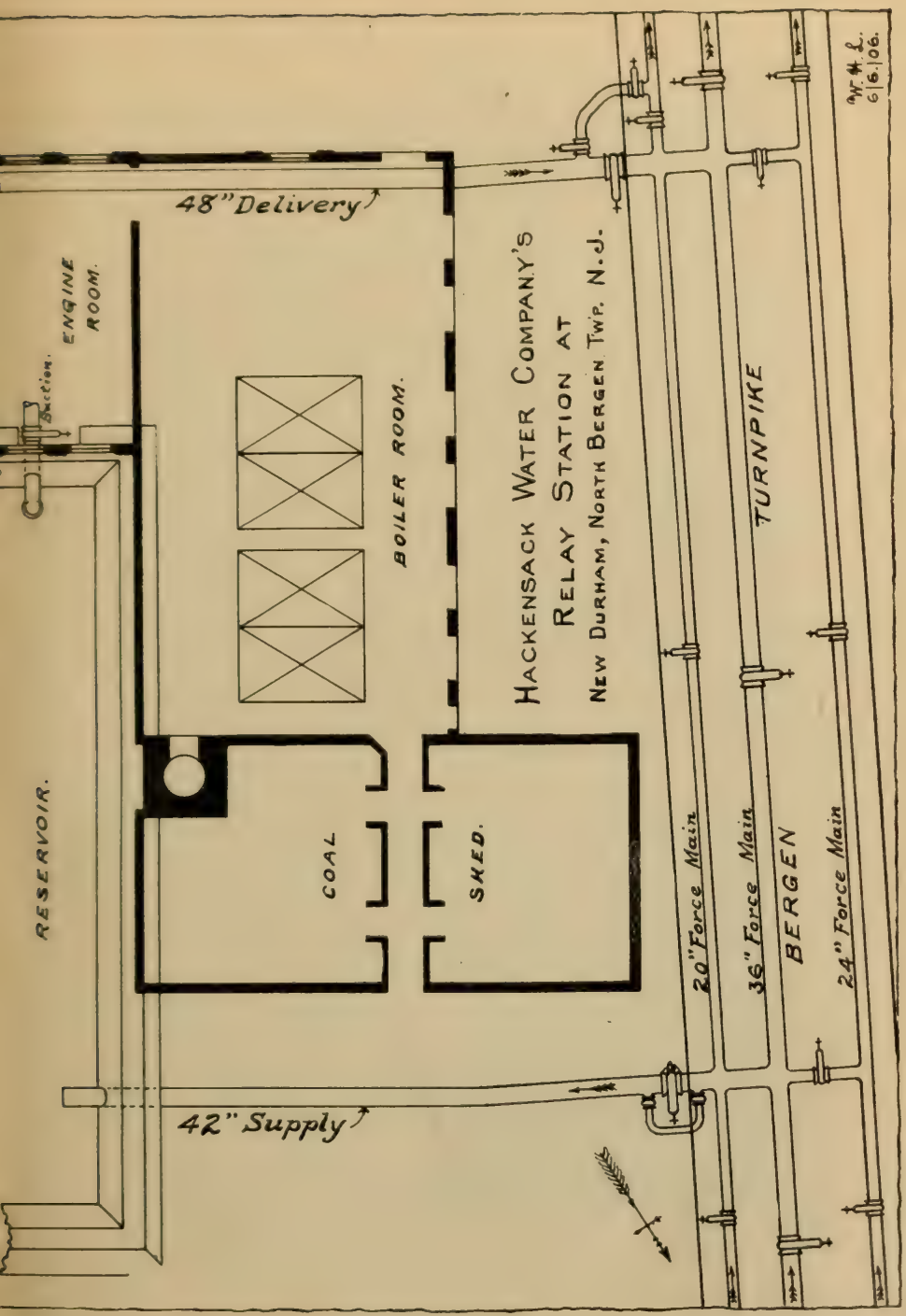
The three mains referred to are laid over elevations varying from 5 to 185 feet, the latter figure being the elevation at the extreme south end of the force main system.

About five miles south of New Milford an elevation of 153 feet was met, and after passing this point the mains are at an average elevation of practically 40 feet, and at New Durham, which is 10,000 feet north from the Weehawken reservoirs, the elevation is 7 feet.

It had occurred to the author of this paper that a relay pumping station could be switched into the force main system at New Durham, by doing which water could be drawn off from the three mains into a reservoir also located at a low level, and at a rate which would perhaps double the velocity in the mains.

If this theory were practicable it seemed possible to double out capacity at a point within two miles of the Weehawken reservoirs, and then by pumping the water back again into the same mains from which it was drawn, except against the opposite side of closed valves and through a short leg of the force main system, it figured that we could easily double the capacity through the two miles of mains, by getting rid of a tremendous loss of head due to friction.

In other words, the capacity of the three mains from New Milford to New Durham, each about 70,000 feet long, would be the same practically as the capacity of the same mains from New Durham to the Weehawken reservoirs, each about 10,000 feet long.



Sketch Showing Arrangement of Mains and Valves for Controlling Supply to and from Station.

(See sketch, valve system, etc.)

In order that some reliable data could be obtained and that could be used for a sound argument, two 12-inch blow-off connections were made to the 36-inch main.

Knowing that a considerable quantity of water drawn from the blow-offs would submerge many acres of the low adjacent flat lands, and possibly cause somebody some embarrassment in answering questions, it seemed worth while to wait for a suitable opportunity before opening the gates, and if possible, to appear to throw some of the responsibility for complaint elsewhere.

Since its organization our company has maintained a rain fall record in connection with its system, and shortly after preparations were completed the gauge indicated a fall of over two inches occurring on a Saturday night, and with the country well afloat anyway, it seemed under the circumstances that it was a most opportune time to open the 12-inch gates.

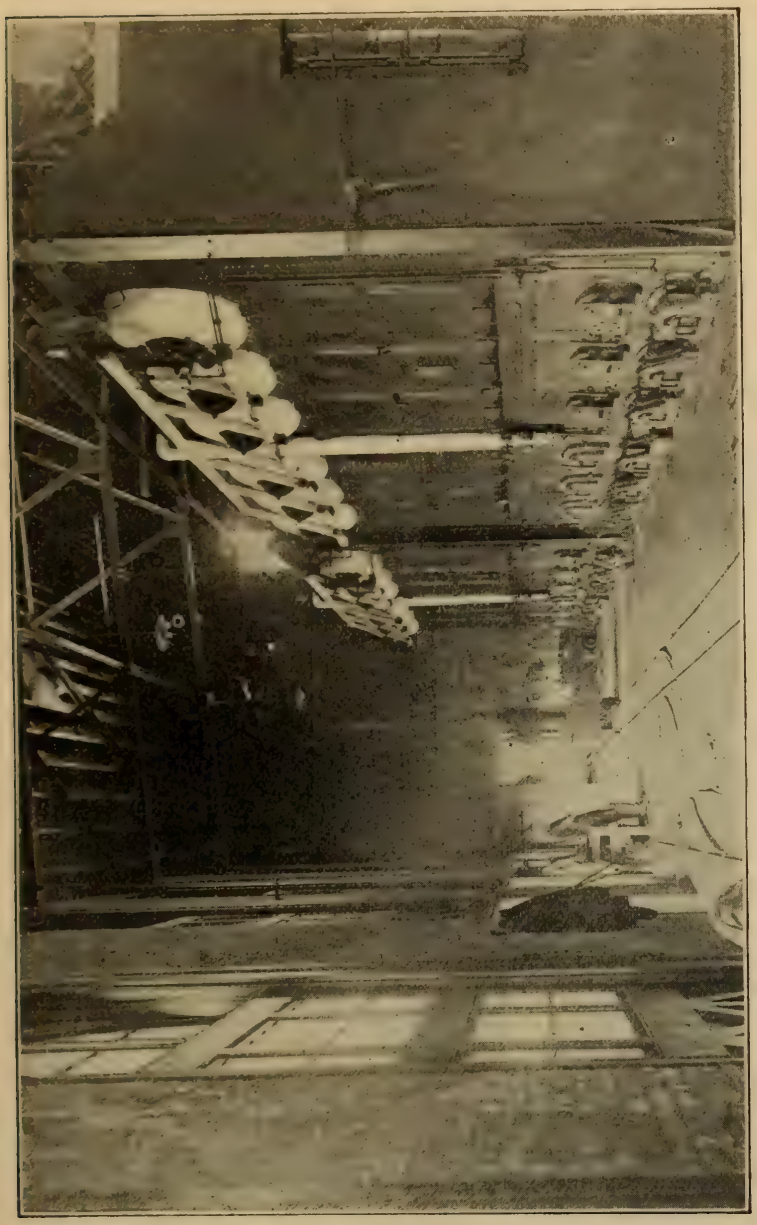
At the New Milford station a twelve and an eighteen-million-gallon engine were in daily use, and after completing all arrangements, and closing all by-pass connections between the 36-inch main and the two smaller ones, the 12-inch valves were slowly opened, which was followed by an immediate increase in speed of the engines at New Milford.

After the 12-inch valves were full open and enough time had elapsed for the engines to become steady, we found the delivery to be at the rate of 26,000,000 gallons per day, against a water pressure of 108 pounds, and through the large main alone, as compared with practically 20,000,000 gallons against a water pressure of 120 pounds, with all three mains in service.

This rate of delivery would have been considerably greater had we been able to hold our steam pressure up sufficiently to have maintained 120 pounds water pressure.

All of the visiting friends and relations of the New Durham natives continue to hear the wonderful "cloud burst" story which all but swept the town away one Sunday some two and one-half years ago.

After this test was made it was a simple matter to estimate the quantity of water that could be drawn with the three mains in use, and mainain a water pressure at New Milford from 115



New Durham Plant, Hackensack Water Co., Boiler Room.

to 120 pounds, and a report was made to the Water Company's Board of Directors that the present mains without laying any additional pipe could be depended upon to furnish a supply until such a time as the total daily consumption approached 40,000,000 gallons, and recommended means be taken to handle the water a second time at New Durham, which recommendation was immediately adopted.

Following this report steps were taken to secure land at a suitable location, contracts were made for construction of reservoir, foundations and buildings, for a complete plant to be equipped with 2,000 horse power of boilers, with economizers and super-heaters, also one twelve and one twenty-million engine of the Allis-Chalmers vertical triple expansion type.

The erection of the engines, boilers, etc., was practically completed in September, 1905, which was prompetly followed by an attempt to test the quantity of water that could be delivered at New Durham and still supply the numerous towns and boroughs to the north.

With all of our high pressure boilers at New Milford under steam, and with a ten million High Duty Worthington, a twelve and an eighteen-million Allis-Chalmers engines all moving, it was found that the delivery was practically at the rate of 37,000,000 gallons per day, of which quantity 34,000,000 gallons were being drawn from the three mains at New Durham.

As the volume mentioned is within 3,000,000 gallons of the original estimate, it seems certain to predict that the demand north from New Durham will equal, if not exceed, 3,000,000 gallons between the time test was made and when the total consumption of the territory supplied reaches 40,000,000 gallons per day.

The total cost of the New Durham plant, including land, reservoir, foundations, buildings and their complete equipment was $423,000.00.

If instead of building this plant a new main had been laid from New Milford to Weehawken, it would have required a 42-inch main to have increased the capacity of the system to the extent the New Durham plant has provided, and the cost of 42-inch main, 85,000 feet long, including rights of way, land damages, crossing a river 1,200 feet wide on a pile foundation, to-

gether with considerable rock excavation, is estimated at $1,063,000.00.

While there is a difference between these figures of $640,000.00, this amount does not cover the total advantage in favor of the New Durham plant.

Since 1883 the company has been operating a high service station at Weehawken, N. J., and located at an elevation of practically 170 feet.

Water was drawn from an adjoining reservoir at elevation 180 feet, and pumped to a high service reservoir at elevation 318 feet. The high service district of the Hackensack Water Company is quite an important part of its system, and at the present time has over 90 miles of pipe, in sizes from 6-inch to 36-inch, and over 9,100 house and factory connections.

The New Durham station is so arranged that water is distributed to both low service reservoirs at elevation 180 and 194 feet, as well as to the high service reservoir at elevation 318 feet at the same time, through an independent system of mains and independent machinery, but by the same force of help, which enabled us to abandon the Weehawken high service station not only, but the cost of operations at New Durham, due principally to a modern equipment in every way, will result in a decrease in cost of operating expenses of from $7,000.00 to $8,000.00 per annum, which capitalized at 5 per cent. would represent interest on a $150,000.00 expenditure.

The inquiry might reasonably be made why locate this plant at New Durham, or why at any particular point off the force mains between New Milford and Weehawken, and replying to such a possible inquiry wish to state, that the success of the undertaking depended largely upon its location, for the reason that somewhere between New Milford and Weehawken, with all grades and elevations taken into consideration, there was a point where there would be a balancing of the whole system, or, in other words, that somewhere within the distance mentioned there was a point at which a certain volume of water could be drawn off from the three mains, and from which point the same quantity of water could again be pumped back into the same pipe system.

Located as the station is, an equal volume of water can be received and discharged, but if for example the station were

located one mile north, while it would be possible to draw from the three mains practically 45,000,000 gallons, the capacity to Weehawken would be reduced to 37,000,000 gallons, the falling off being due to the additional friction loss in the extra mile of mains.

With the plant located at New Durham we feel that we have made the best possible use of the present system of force mains and with results which are exceedingly satisfactory both as to first cost and operations.

MR. FRENCH:—Since this paper was prepared there has been an official test made of a 12 million gallon Allis engine located at this station. Inasmuch as the test has broken the record of the Allis engine tested at St. Louis, I think in February of the present year, and at the present time holds the world's record for duty, I felt it would be worth while to add this information to the paper, thinking it would be interesting to many of the members.

OFFICIAL DUTY TEST OF TWELVE MILLION GALLON PUMPING ENGINE.

FOR HACKENSACK WATER COMPANY, AT NEW DURHAM, N. J.

This engine is of the vertical, triple expansion, condensing, crank and flywheel type, having a single acting plunger located under each of the three cylinders. It is self contained and has a total height of forty-three feet.

The contract contains the following guarantee regarding the duty test:

"We guarantee this engine to deliver twelve (12) million U. S. gallons of water in 24 hours, against a total head of 334 feet, when running at a plunger speed of not more than 208 feet per minute (26 revolutions), and to develop a duty of 168 million foot pounds for each one thousand pounds of dry steam used by the engine, work done to be based on plunger displacement."

The formula for determining the duty was as follows:

$$\text{DUTY} = \frac{\rho\, d^2\, 3\, S\, W\, h\, r}{4 \times 144} \quad \frac{1000}{T}$$

d = diameter of plungers	inches	26.0
S = stroke of plungers	feet	4.0
W = weight of one cubic foot of water	pounds	62.36
h = head pumped against	feet	334.7534
r = revolutions in 24 hours		36,612.
T = dry steam furnished to engine	pounds	186,377.

$$\frac{\rho\, d^2\, 3\, S\, W\, h\, r}{4 \times 144} = \text{foot pounds in 24 hours,} \quad 33{,}815{,}092{,}250.$$

Duty per 1000 pounds of dry steam	foot pounds	181,433,826
Duty required by contract	foot pounds	168,000,000
Actual duty in per cent. of required duty		108.0

Diameters of plungers and strokes were carefully measured and all instruments and apparatus tested before the test and in some cases, as suction and discharge gauges, immediately afterward.

All pump valves were examined and tested immediately before the test and found to be tight.

Indicator cards were taken hourly during the test.

The revolution counter and all gauges and thermometers were read every fifteen minutes.

The air pump, feed pump and air compressor are permanently attached to the low pressure plunger and were in operation continuously during the test.

All condensed steam from the air pump was discharged through a three-way cock, alternately into two galvanized iron tanks resting on weighing scales. These tanks had a capacity of about 1,100 pounds of water and were weighed every 9 minutes. After weighing, the water was wasted to the sewer.

Receiver and jacket drains were measured collectively in a carefully calibrated tank. Before reaching this tank, they were passed through condensing coils, thereby preventing any possible loss by evaporation.

The steam pressure was read by a Crosby test gauge located at the engine throttle and the quality of the steam was determined by a Barrus throttling calorimeter similarly placed. The steam was found to be practically dry.

The suction and discharge pressures were taken by carefully calibrated test gauges located in the suction and discharge pipes, close to the engine, and the head pumped against was

taken as the difference between these two readings. The suction head averaged about 1 foot and the discharge was throttled to give the required head.

The drains from plunger packing were observed carefully and showed no perceptible leak. The same was true of the valve stem packings.

The vacuum in the exhaust pipe close to the low pressure cylinder was measured by a mercury gauge and the temperature was taken at the same place. The pressure in the low pressure jacket was measured by a mercury column. The temperature of the L. P. jacket drain and first and second receiver drains were taken by thermometers inserted in these pipes. The temperature of the water pumped and of the air pump discharge were taken hourly.

GENERAL DATA.

Date of Test	May 29-30, 1906	
Duration of Test	24 hours.	
Type of Engine	Triple Expansion	
Diameter H. P. Cylinder	inches	30.0
" I. P. "	"	54.0
" L. P. "	"	84.0
" Piston rods	"	5.5
" Plungers	"	26.0
" Feed pump	"	2.75
" Air compressor	"	3.00
" Air pump	"	24.0
Stroke of all Cylinders and Pumps	"	48.0
No. of plungers	"	3.
Kind of plungers, single acting outside packed.		
Clearance H. P. Cylinder top	per cent.	1.99
" H. P. " bottom	" "	1.45
" I. P. " top	" "	1.567
" I. P. " bottom	" "	1.396
" L. P. " top	" "	0.769
" L. P. " bottom	" "	0.690
Cooling surface of Condenser	sqr. feet	1,500.
" " " " per I. H. P.	" "	2.02
Cylinders Ratios 1 to 3.24 to 7.84		

PRESSURES.

Steam pressure (initial) by gauge	pounds	176.67
" " " in H. P Cylinder by cards	"	175.4
Steam pressure in 1st Receiver by gauge	pounds	27.52
" " " 1st " " cards	"	27.00
" " " 2nd " " gauge (vacuum)	"	1.40
" " " 2nd " " cards	"	1.30
" " " H. P. Jacket	"	Initial
" " " I. P. " by gauge	"	53.31
" " " L. P. " " "	"	1.03
Vacuum by gauge	"	14.23
" " Mercury column, exhaust pipe	inches	27.39
" " cards	pounds	13.20

TEMPERATURE IN DEGREES FAHR.

Water pumped	62.6
Drain from 1st Receiver,	211.10
" " 2nd "	151.45
" " L. P. Jacket,	193.5
Water discharged from Air Pump,	79.50
Exhaust steam in pipe near L. P. Cylinder,	111.79
Steam (Initial)	378.5

STEAM.

Total water from surface condenser,	pounds	163,074
Water from surface condenser per hr.	"	6,794.75
Total water from Jacket and Receiver drains,	"	23,303
Total water from Jacket and Receiver per hr.		970,958
Quality of steam at throttle,	per cent.	100.00
Total dry steam chargeable to engine	pounds	186,377
Total dry steam chargeable to engne per hr.	"	7,765.71
Jacket and Receiver drains,	per cent.	12.50

PUMP DATA.

Total revolutions		36,612
Revolutions per minute,		25.425
Displacement of Plungers per revolution,	pounds	2,759.066
Displacement of Plungers per revolution,	gallons	330.97
Displacement of Plungers per revolution,	cu. ft.	44.24417
Total water pumped,	gallons	12,117,474
Average head	feet	334.7534
Total foot pounds in 24 hours,		33,815,092,250

INDICATOR CARDS.

Indicated horse power,	743.7
Delivered horse power	711.6
Total friction horse power (Mech. and Hyd.)	32.1
Per cent. of Friction, ,	4.316

INDICATOR CARD DATA.

		Top.	Bottom.
Area H. P. Piston	sq. inches	706.86	683.10
Area I. P. Piston	sq. inches	2,290.22	2,266.46
Area L. P. Piston	sq. inches	5,541.77	5,518.01

HIGH PRESSURE CARDS.

Scale of Springs	90	90
Initial Pressure (absolute)	190.0	190.2
Cut off Pressure (absolute)	188.8	189.7
Release Pressure (absolute)	51.2	51.7
Per cent. of Cut Off	21.2	23.9
Mean effective pressure	65.0	67.6
Indicated horse power	142.1	142.8
Indicated horse power total	284.9	

INTERMEDIATE PRESSURE CARDS.

Scale of Spring,	20	20
Initial Pressure (absolute)	41.8	41.6
Cut off Pressure (absolute)	37.7	36.9

Release Pressure (absolute)	13.5	14.0
Per cent of Cut off	35.6	35.2
Mean effective pressure	13.92	13.61
Indicated horse power	99.2	96.2
Indicated horse power total	195.4	

LOW PRESSURE CARDS.

Scale of Spring,	10	10
Initial Pressure (absolute)	12.9	13.9
Cut off Pressure (absolute)	12.4	12.5
Release Pressure (absolute)	5.4	5.0

LOW PRESSURE CARDS.

Per cent. of Cut off	34.6	36.4
Mean effective pressure,	7.40	7.87
Indicated horse power	129.3	134.1
Indicated horse power total	263.4	

SUMMARY AND RESULTS.

Dry steam per I. H. P. per hour, pounds,		10.442
Dry steam per D. H. P. per hour, pounds,		10.913
Duty per 1000 pounds dry steam, foot pounds,		181,433,826.
Duty per million B. T. U., foot pounds,		159,812,436.
B. T. U. per I. H. P. per minute,		197.58
B. T. U. per D. H. P. per minute,		206.49
Mechanical efficiency,	per cent.	95.684
Thermodynamic efficiency,	per cent.	21.47
B. T. U. chargeable to engine,		211,592,371.
Actual efficiency,	per cent.	20.543

As furnishing a comparison between the St. Louis engine and ours these figures seem to me to be quite remarkable for several reasons. To begin with, the St. Louis engine was a 20 million gallon engine, which is very much more favorable for higher results than a 12 million gallon engine. Again, the St. Louis engine had a 60-inch stroke as compared with the 48-inch stroke of our engine, another fact tending to place the St. Louis engine in a more favorable position as regards results of test. The St. Louis had further been running steadily for about a year, I am told, whereas in our case the machine had only been operating between five and six months, about nine hours per day. The character of the contract also favors the St. Louis machine somewhat, and is known as a penalty and bonus contract, according to which the city was to be paid a certain amount of money for each million foot pounds it fell short of the guarantee, and on the other hand the city was to pay the contractors a like sum for each million foot pounds developed in excess of the guarantee.

The result was that it was to the financial advantage of the contractor to exceed the guarantee requirement just as much as possible. In our case the contract was a penalty contract without a bonus, so that there was no particular desire on the part of the contractors to do anything more than to fulfil the contract conditions and to slightly exceed the guarantee.

MR. DAVIS: How did you make the test—by weir?

MR. FRENCH: No,—by plunger displacement. The engine is an outside packed single acting plunger, triple expansion machine.

EXPANDING WATER SUPPLY SYSTEMS.

J. T. Fanning, C. E.

A thriving young city is surely destined to be in time perplexed with complaints that the water pressure in its distribution mains is insufficient, nothwithstanding the quantity of water at its source may be ample. Such complaints come sooner if the city grows fast, and also if the locality is undulating, so that fine residences are built upon suburban hills that are fifty to one hundred feet higher than the business section. Such complaint comes sooner if the source, or pumping station, is far to one side of the city, or if tram lines encourage the building up of suburban groups of residences or manufacturing centers far to one side of the city and opposite to the site of the pumping station or reservoir.

Where there are direct pressure systems of pumping for fire services the lack of water pressure at times of large draft of water is often erroneously attributed to a weakness of the pumps, while the officials know that the pumps are in good order and give, when required, full one-hundred pounds per square inch water pressure at the station when a fire is in progress. Sometimes the citizens suspect that the pipes are filled with sediments, or with algae or with tubercles so that the water cannot flow in sufficient quantity to give the desired pressure. As cities grow the pipes are extended, and the draft of water increases, but rarely do more than few of the citizens, and perhaps rarely do more than parts of the city councils recognize that *lengths* of the main and distribution pipes and increased *velocities* of flow have both important effects in the losses of pressure.

Work must be done, either by pump pressure or by gravity head, to press water through a pipe with rapid flow, as when there is a draft for fires. The work done to give velocity of flow of water in such case in a straight pipe is in proportion to the square of the velocity of flow, so that if the rate of flow is doubled in a given pipe the work done is quadrupled. Also if the length of the given pipe is increased the work done to press the given quantity of water forward is increased in proportion as the length of the pipe is increased, and this work is being done in

increments all along the length of the pipe. The total of this work is the product of the pressure into the given rate of motion of the flowing water, and in such case is called friction of flow, and may be expressed in the equivalent of feet head, or pounds per square inch, as, for instance, if a pump has to press water through one mile of 12-inch pipe lying level with the pump at the rate of one million gallons per 24 hours, then the initial pressure must be equivalent to 7.13 feet head, and if the rate of flow is increased to two million gallons per day then the initial pressure must be increased to an equivalent of 28.5 feet head, the initial pressure varying with the square of the rate of motion.

Then, if the same pipe is increased to two miles length the work or pressure in feet head for a given flow will be doubled, and if to four miles length the work or pressure will be quadrupled.

In usual practice the cause of complaint appears in a different form, for when a fire is in progress the pressure is maintained constant at the pump house, thus, if the pressure at the pump house is 100 pounds per square inch, or equivalent 231 feet head, then in the four miles of twelve-inch pipe above, the reduction of pressure at the discharge end of the pipe would be 28.52 feet of head when the flow was at the rate of one million gallons per day and 114 feet of head when the flow was at the rate of 2 million gallons per day.

These are elementary statements and familiar to water works officials, but they are not familiar to citizens or city councils generally, and the water department officials ought to impress them upon the citizens by many repetitions, for it is the citizens who must provide the cash to remedy such causes of their own complaints.

Such losses of pressure in distribution pipes, when there is a strong flow in one direction only, may be clearly presented in tabular form for a moderate number of conditions that are not unusual, and the consideration of them may be simplified by first taking cases showing losses due to flow for fire streams alone.

FRICTION HEAD LOSSES IN PIPES,

When 1⅛ inch Hose Nozzles are Used.

No. of 1⅛ inch Fire Streams.	Rate of Discharge in Mill. Gals. per 24 hours.	Diameter of Main Pipe. Flow in one direction.	Friction loss of head per 1,000 feet of pipe	Friction loss of head per mile of pipe.
1 Stream.	1-3 Mill.	6 inch.	5.3 ft.	27.98 ft.
1	1-3	8	1.4	7.39
1	1-3	10	.48	2.53
3	1	8	10.6	55.97
3	1	10	3.6	19.00
3	1	12	1.36	7.18
4	1 1-3	10	6.1	32.21
4	1 1-3	12	2.4	12.67
4	1 1-3	14	1.1	5.81
6	2	10	13.4	70.75
6	2	12	5.35	28.25
6	2	14	2.5	13.20
6	2	16	1.22	6.44
9	3	12	11.6	61.25
9	3	14	5.38	28.40
9	3	16	2.73	14.41
9	3	18	1.56	8.24

FRICTION HEAD LOSSES IN PIPES.

When 1¼ inch Hose Nozzles are Used.

No. of 1¼ inch Fire Streams.	Rate of Discharge in Mill. Gals. per 24 hours.	Diameter of Main Pipe. Flow in one direction.	Fricion loss of head per 1,000 feet of pipe.	Friction loss of head per mile of pipe.
1 Stream.	½ Mill.	6 inch.	13.1 ft.	69.17 ft.
2	1	8	10.65	56.23
2	1	10	3.56	18.80
2	1	12	1.36	7.18
2	1	14	.65	3.43
4	2	10	13.4	70.75
4	2	12	5.35	28.28
4	2	14	2.5	13.20
4	2	16	1.22	6.44
6	2½	12	8.2	43.30
6	2½	14	3.8	20.06
6	2½	16	1.9	10.03
6	2½	18	1.1	5.81
8	4	14	9.3	49.10
8	4	16	4.75	25.08
8	4	18	2.7	14.26
8	4	20	1.5	7.92
10	5	14	14.3	75.50
10	5	16	7.33	38.70
10	5	18	3.95	20.86
10	5	20	2.33	12.30
10	5	24	0.95	5.02

The tabled volumes of flow and friction losses are, of course, enhanced by the added domestic flows. In small cities the proportion of the supply pipe required for the domestic flow seems insignificant as compared with the proportion required for fire extinguishment flow, but as cities grow the domestic flow percentage increases, while the fire flow percentage decreases.

In considering the combined rates of flow in distribution pipes, for both domestic and fire purposes, it will be interesting to note the relative proportions of the pipe capacities required for the domestic and fire purposes, in the same city, as it grows, or in different cities with different populations.

COMBINED DOMESTIC AND FIRE FLOWS.

Population	5,000	10,000	25,000	50,000	100,000
Average gallons per person, daily	60	65	70	80	90
Domestic rate, daily, Mill. Gals.	0.30	0.65	1.75	4	9
No. of good 1⅛-in. Fire Streams	8	10	12		
No. of good 1¼-in. Fire Streams				14	16
Fire Rate, Mill. Gals.	2.67	3.33	4	7	8
Combined domestic and fire rates, Mill. Gals.	3	4	5.75	11	17
Min. diam. of single main, inches, for single flow	14	16	18	24	27

The table indicates the portion of the supply main required for the *domestic flow* at the times when there is also a fire flow, and for different populations, is as follows: For 5,000 population 11.24 per cent., for 10,000 population 19.52 per cent., for 25,000 population 43.75 per cent., for 50,000 population 57.14 per cent., and for 100,000 population 88.89 per cent. In larger cities the domestic flow requires one-half and more of the supply main capacity of the combined flow. The cost of the fire service capacity in the water mains is relatively greater in the small than in the large cities, and relatively greater in the suburban than in the urban streets.

If the supply main continues of the same diameter or is not reinforced as the domestic rate of flow increases, then it must be remembered that the pressure losses vary more rapidly than the flow rate increases, for if by increase of domestic consumption the total flow is increased fifty per cent. the friction loss is increased as $1.^2$ to 1.5^2, or one hundred and twenty-five per cent.

Friction losses of pressure are more excessive in fire hose than in the pipes, because, owing to the small diameter of the hose, the velocity of flow is great.

A 1⅛ inch smooth hose nozzle, having a water pressure at

the nozzle of 40 pounds per square inch, will deliver approximately 231.5 gallons of water per minute, or at a rate of ⅓ million gallons per day.

A 1¼ inch smooth hose nozzle, having a water pressure at the nozzle of 55 pounds per square inch, will deliver approximately 347.2 gallons of water per minute, or at a rate of ½ million gallons daily.

The friction losses of head in each 100 feet of 2½ inch smooth hose when delivering the above quantities of water is indicated by the following table when the friction loss, *h*, in the hose is computed by the formula:

$$\text{For head, } h = \frac{lq^2}{1800d^5} \text{ or for pressure, } p = \frac{lq^2}{4157d^5}$$

in which d = diameter of hose, in inches, l = 100 feet, q = gallons per minute, h = friction head lost, in feet, and p = lbs. per square inch.

	Pressure at Nozzle.	Gallons per minute.	Friction head per 100 ft. of 2½ in. hose.
1⅛ inch Hose Nozzle	40 lbs.	231.5 gals.	30.48 ft. = 13.19 lbs.
1¼ inch Hose Nozzle	55 lbs.	347.2 gals.	68.57 ft. = 29.69 lbs.

The friction losses in the long distribution pipes lead to inadequate pressure for domestic service on the high grounds, and in high buildings. The friction losses in the long pipes and in the long hose lead to loss of height or distance to which fire streams can be thrown, or to a diminution of the quantity of water discharged by each fire stream, and usually to both loss of volume of water discharged and strength of stream, until the streams are inefficient for fire protection, especially when the hose lengths are considerable. Therefore, there is just cause of complaint, and complaints are frequent. When the citizens clearly understand the true causes for their complaints they will usually provide funds for the remedy to the extent of their financial ability, whether the complaints are as to inefficiency of the system or to impure quality of the water supply.

When the pipe system has expanded to an undue overgrowth, a new capacious reinforcing main, passing through and connected with the branch pipes of a former main, and carrying a free flow and strong pressure of water toward the extremities of the system, is a first remedy demanded. Such duplicate main will not only improve the efficiency of the flow and pressures, but will add greatly to the protection of the city by providing a second line of supply in case of injury to the first line, and will provide many facilities for such better operation and care of the system as the Superintendent well understands.

When the buildings are three or more stories in height there should be two hydrants at each street intersection, and where the city blocks in business sections exceed 450 feet in length there should be a hydrant near the middle of the block.

The great losses of pressure in each one hundred feet of hose, above shown, emphasizes the fact that hose lengths should not exceed 250 feet, unless the hose lines are doubled, and therefore that fire hydrants should not be widely separated. Good hydrants are not expensive in maintenance, while hose is short-lived in its full strength. Hydrants are cheaper in the long run than hose, and are much less liable to fail at a critical time.

The above tabled losses of pressure apply to flows in one direction in a single pipe.

The flow of water toward a hydrant should be from two directions and to distant parts of the system through duplicate mains, so that the velocity of flow may be halved and the loss of pressure due to flow reduced to one-fourth that of an equal quantity of single flow. The disposition of the large distribution pipes, to be added as the pipe system expands, should be in accordance with a reinforcing system so as to conserve the pressure at all points, and give a duplicate flow to all points, and thus give the best service at all points for both domestic and fire purposes.

The maintenance of each water supply system in the highest state of efficiency is of such supreme importance that the citizens should be constantly taught that the city best prepared to promptly and effectively fight a fire at its inception is the city having the greatest probability of sparing itself the awful penalties of a great conflagration.

Discussion

Mr. Hague:—I think that that part of Mr. Fanning's paper which refers to the loss of pressure in fire lines is a very important one, and it is a branch of the subject that you cannot think too carefully about. Very often in smaller cities where the direct service is in use there will be ample pressure at the pumping station, but at the point of the fire where the water is used the pressure will sometimes be so low as to make people think that there is something wrong with the pumping machinery and the distributing system; whereas, as a matter of fact, in a great many cases the pipes are so small that the quantity drawn off from the pipes reduces the pressure so at the hydrant in order that the flow may take place that the fire service is practically robbed of a great deal of its usefulness. City Councils and city officials generally, including, of course, water works officials, cannot think too carefully about this matter of low friction losses in fire mains. The writer gives some tables that refer to fire streams which I think are very reasonable, as to amount of water discharged per minute, pressure required in the flow, etc. He also refers to the location of fire hydrants and the number of fire hydrants. I have given this matter of fire protection a good deal of thought in the last few years. It strikes me that hydrants are very much cheaper than hose. Not only that, but with short lengths of hose the water is delivered from the hydrants under pressure nearer to the fire, which pressure is greater than possible to obtain through an extended line of hose. A fire hydrant set in a place probably would not represent over $40 to $50, while good hose is worth a dollar a foot; so you see you are not saving very much by buying more hose and setting less hydrants. It is also very important to get the water quickly and under sufficient pressure, for, as you all know, fires work overtime and do not wait for anybody. It is the first fifteen or twenty minutes that often determine the course of a fire, and whether or not it will develop into a conflagration. The man who pays the premium charge is made good; it is the insurance company that pays the real loss. Therefore, underwriters are very careful to raise a great many

points, and they would not probably object to having twice as many fire hydrants set as you generally find in our cities.

The writer refers to the flow of water through hydrants from different points, which I also consider very important. All possible cross connections should be made, so that when a draught takes place in this, that or the other section of the city, water may be delivered where needed with the least loss of pressure. Within the past two or three years I have seen two or three very striking examples of the running of a large artery main through the heart of a city with plenty of cross connections raising the pressure throughout the district from 40 to 100 per cent. The city had prior to applying this remedy outgrown the system, and people did not realize it until a large fire stirred them up and this remedy was applied, then they were astounded at the amount of improvement in pressure thus obtained. The following table shows a portion of the city affected, and the improvement of the pressure in that section:

A COMPARATIVE STATEMENT OF PRESSURES BEFORE AND AFTER LARGE FEED MAINS WERE TURNED ON, OCTOBER 5TH, 1905.

LOCATION WHERE PRESSURES WERE TAKEN.	Record of pressure in lbs. per sq. in. before large mains were turned on.		Record of pressure in lbs. per sq. in. after large mains were turned on.	
	Pressure	Time Taken	Pressure	Time Taken
Broad and Hanover	26	4:15	38	4:15
Hanover and Montgomery	25	4:10	37	4:10
City Hall	26	4:20	38	4:20
Willow, at Rickey's Coal Yard	27	4:30	30	4:30
Princeton & Pennington	26	10:45	28	10:45
American Bridge Co.	20	1:00	29	1:00
Thos. Maddock Sons' Pottery	23	1:40	30	1:40
Clinton and Mott	23	1:50	31	1:50
Star Porcelain, Muirheid St.	26	1:55	32	1:55
Mulberry St. and New York Ave.	21	2:25	26	2:25
Trent Tile, Klagg Ave.	27	2:15	34	2:15
Clinton and Greenwood	19	3:55	32	3:55
Clinton and Hamilton	20	3:50	33	3:50
Clinton and Mott	22	3:40	36	3:40
Court House	20	8:30	35	8:30
Broad and Second	20	8:45	35	8:45
Broad St., at Canal	18	8:55	33	8:55
Third and Federal	14	9:05	27	9:05
Cass and Second	16	9:20	26	9:20
Trenton Brewery	18	9:30	30	9:30
Mott Iron Works	19	9:50	29	9:50
Hancock, at end of line	23	10:15	37	10:15
Broad and Jennie	19	10:30	36	10:30
Roebling and Jennie	17	10:40	29	10:40
Division and College	21	3:30	31	3:30
Hamilton and Chestnut	17	3:20	28	3:20
Greenwood and Logan	25	3:00	32	3:00
Reeves Machine Works	27	2:45	34	2:45
Acme Pottery Co.	23	8:15	23	8:15
Pennington and Willow	20	11:00	32	11:00

H. F. Dunham: The method introduced by the author of this paper is a valuable one and will be appreciated by those in charge of works, but a method is similar to a formula in the particular mentioned by Roland, that you cannot get out of it more than has been put into it, and in the speaker's opinion, the author failed to put in enough.

The average daily consumption in cities of widely varying populations is given and the quantity of water for efficient fire streams is also given. From these two items the total quantity for both domestic and fire protection demands is determined by simple addition.

If fires occurred only in April and October, and during those hours of the day when the domestic use was close to the average for the year, and if domestic pressure and fire pressure were always the same, the tables given would be quite reliable and satisfactory. But domestic use varies with the season, and with the hour of the day, domestic pressure is usually less than fire pressure, and fires will occur at all hours and under all sorts of conditions.

Because these things are so, and must be recognized, the speaker believes it would be nearer the truth for a city of fifty thousand inhabitants to provide for the demand due to domestic use alone not less than seven million gallons, where the author makes provision for but four million, in addition to the demand for fire streams.

This defect or failure to regard conditions as they exist may be found not only in the tables, but in the calculations for flow in force mains. It may be questioned whether figures should be used for reference, or from memory, when it is known that they are in error from fifty to one hundred per cent. during a considerable part of the time that a water works is to be maintained.

THE GROWTH OF THE PUMPING STATION.

By Charles A. Hague.

The pumping station herein referred to is the regular water works pumping station devoted to municipal supply, and specimens of which may be found scattered broadcast over this great land, wherever a community has mustered sufficient courage and progressiveness to establish a system of water works requiring the placing of water under an artificial head or pressure.

The capacities of pumping engines and the dimensions of buildings to contain them, have been on the general increase ever since 1878, a period from which dates the beginning of the wonderful development and rapid building of plant after plant for public supply, to say nothing of the enlargement and improvement of plants already existing in cities large and small.

Thirty years ago pumping engines of 2,000,000 to 5,000,000 gallons daily capacity were considered of quite some importance, and they were to the communities buying and using them. Occasionally a machine of greater capacity than these came into existence, going perhaps as in the case of Chicago and other large western cities as high as 10,000,000 gallons. Chicago, early recognizing the fact that she must depend altogether upon pumping and seeing the shadow cast forward by coming events, even going to the extent of installing pumping engines having a capacity as high as 30,000,000 or thereabouts. But these large machines were exceptional and only occasionally found; the great mass being of very much smaller dimensions, it even being thought in some very important quarters not many years ago that 10,000,000 gallons per 24 hours would eventually mark the top limit for capacity of the unit in pumping.

But nowadays the 10,000,000 gallon machine is left far behind in the march of improvement, and in the tremendous development of the country, until it has come to pass that 12,000,000 is considered moderate and reasonable; 15,000,000 common; 20,000,000 not unusual; and 25,000 000, 30,000,000, and even 40,000,000 not surprising. For special purposes, like

sewage pumping, for example, any one in the vicinity of Boston may investigate a 72,000,000 gallon pumping engine, if desiring to do so. In water works pumping it seems to be a question of unit in proportion to the gross demands, and it will pay any one responsible for the quantity, cost, and quality of water for public supply, to carefully consider the relations between the above mentioned items. A good rough rule in a growing plant, occasionally enlarged, is to install each new engine of a capacity equal to the sum of the capacities of the engines already in place, until the new engine reaches the limit of the size of unit appropriate for the plant in question. For example, if a plant has been started with two 5,000,000 engines, when a new one goes in, make it a 10,000,000 engine; or if started with one 5,000,000, and afterwards supplemented with a 10,000,000, after that put in a 15,000,000 engine. The rule must sometimes be modified by taking into account the average and the maximum pumpage, but the general idea is to keep the unit and multiple idea in mind so as to facilitate changing about, and using the reserves to the best advantage. Then by having an eye to the possible enlargement of buildings without entirely destroying the plant, so to speak, much lost time, trouble, and money will be saved.

In the growth and development of the pumping station, refinement in machinery, and reduction in cost of manufacture, through better and more appropriate designing, coupled with more efficient and economical shop management, gradually led to higher and higher duties in steam economy, and this gradually changed designs and consequently sizes and forms of buildings. The old fight between low first cost and low duty, and high first cost and high duty, gradually quieted down by the great advocate of low duty and low interest accounts finally being forced to enter the field of a higher economy or retire to the back ground. He entered it and kept his colors well to the front for many years, but the simplification of the crank and fly wheel engine and the increasing complication of the direct acting engine from the very nature of the common aim of both towards high steam expansion, has gradually placed them upon equal footing, so far as cost of construction is concerned, and there are undoubtedly certain items in the designing of the machinery like close clearance space, for exam-

ple, in which the absolute control of the stroke by the crank gives that type of engine some slight advantage in every day work. At all events the duty averaged from a fairly good number of engines gives the crank and fly wheel machine an advantage which makes it necessary to push the direct acting engine along in the market, where the other one gravitates without material assistance.

The higher steam pressures which go hand in hand with greater and greater steam economy, changed ideas on boilers, brought greater horse power per boiler by enlarging the units and gross demands, and lead to restricting the dimensions of the boiler plant so far as practicable. Probably for regular good every day efficiency the horizontal return tubular is as good as any, and better than most. But where large powers are involved, the room required, and the size of the necessary buildings, place a limit upon the consistent size of boilers and units of this type. The writer does not look with favor upon underfired boilers with shells of very large diameter, and, although special and comparatively expensive plants, the designing of which has been in thoughtful and dexterous hands, seem to demonstrate the feasibility of using such boilers occasionally, still in the long run and among the many plants built, the boiler for high pressure made up of parts of comparatively small diameters upon the unit principle, seem to economize space, buildings, first cost of complete plant, and other important particulars in that line, to a very satisfactory degree. To bring this detail directly to a point of issue, if such may prove to be the case, the writer very good-naturedly, in the interests of water works owners, but firmly withal, takes the ground that under present circumstances of unit capacity, gross demands, economy of construction, convenience and economy of operation, together with considerations as to buildings and space required; the water tube boiler fitted with automatic stokers, takes the lead as a general steam generator for water works pumping plants.

And to make this complete, it should be supplemented with the further statement that the limits of steam economy in the pumping engine are about reached, both theoretically and practically. Not to go too far back the duty records have been, and are, as follows:

In the year 1893, 154,048,700 ft. lbs. per 1,000 lbs. steam.
1895, 157,843,000
1898, 167,800,000
1900, 168,532,800
1900, 178,497,000
1900, 179,419,600
1906, 181,068,605

And finally, the leading work has become crystalized into the vertical, triple-expansion machine, with outside packed plungers, and largely of the crank and fly wheel type.

The relation, between the difference in economical duties of pumping engines; and the amount of boiler required; may be conveniently illustrated by the accompanying table. The measurable amount of boiler needed being positively indicated by taking 10 square feet of heating surface for each boiler horse power.

TABLE.

Boiler Horse Power Required for Each Pump Horse Power, Counting 10 Square Feet of Heating Surface Per Boiler Horse Power.

For the Following duties of Engine.

Duty in foot pounds per 1,000 pounds of steam.	Boiler horse power Per Pump Horse Power.
40,000,000	1.63
50,000,000	1.32
60,000,000	1.10
70,000,000	.94
80,000,000	.83
90,000,000	.74
100,000,000	.66
110,000,000	.60
115,000,000	.57
120,000,000	.55
125,000,000	.52
130,000,000	.51
135,000,000	.49
140,000,000	.47
145,000,000	.46
150,000,000	.44
155,000,000	.43
160,000,000	.41
165,000,000	.40
170,000,000	.39
175,000,000	.38
180,000,000	.37
185,000,000	.36
190,000,000	.35
195,000,000	.34
200,000,000	.33

In considering the growth of the water works pumping station, it will be seen that the earlier practice was not free to plan extensively for the future, although it can be seen now that very much better work on this line could have been done than was actually accomplished. The main point is, to look ahead, and calculate as nearly and as clearly as may be, the probable growth of the city and its probable demands in the future for water pumpage. Of course it can not be expected

that actual and accurate prophecy need be indulged in; the principal thing is to think of the matter in some shape or other, and have an idea at least in view, that enlargements are bound to come, and increase in capacity is inevitable in the future. It will surprise many to look the pumping stations over throughout the country and observe what a difference in the cost of extensions could have been made for the better, and to what a great extent inconvenience could have been avoided if the original designers of the plant had comprehended to even a slight degree the value of arranging things upon the unit basis, so that additions could be readily and consistently made. Of course thirty years ago, no one foresaw sufficiently to grasp the idea of the rapid strides in development about to come to the country, and therefore could not naturally have conceived the ideas which now seem so natural. It would not have been necessary to provide extensive and costly buildings, intakes, screens, wells, etc., all at once, and then wait for the demands of the community to grow up to the situation. But rather to arrange and design a plant of comparatively moderate dimensions in proportion to the existing demands, so that it might be enlarged afterwards, unit by unit; and it would have been possible and practicable to introduce enough elasticity into the scheme to meet the varying changes in ideas of improvement which it is now seen has taken place. It is rather surprising what a range of new ideas will be opened up to the mind which has been following too closely a rather narrow channel, and it is well known what a difference the point of view makes very often.

The writer has several cases in mind in connection with his own practice which fully illustrates the idea of looking ahead; and showing what a difference in favor of future economy it will make whether the immediate needs are considered alone without thought for the future, or whether by a slight modification the future is considered. One case in particular which will answer to demonstrate the point was as follows:

In a certain city it had been foreseen for some time that the gravity supply which had so far been the entire dependence, was gradually but surely reaching its limits, and that auxiliary pumping must sooner or later be resorted to. The supply from which to pump was available in very good quantity and quality,

and at length the move was made, and a pumping station built and connected with the mains for supplying the reservoirs. So far so good. But the fact was not clearly perceived, apparently, from the evidence of what was done at least, that pumping once having been resorted to, its increase was inevitable as time went on, and from the very cause which brought pumping into existence; viz., the increased and increasing demand over and above the gravity system capacity. The first pumping station was built just large enough to contain a 5,000,000 gallon engine with the necessary boilers, and a few years afterwards, about five, it became necessary to enlarge the pumping capacity and a 10,000,000 gallon engine was installed. But to place this second engine it was necessary to rebuild nearly the entire station, but the work was carried out in due season, and then the station just snugly contained the two sets of machinery with an extra boiler. Nine years more passed away, and then another move in the direction of increased capacity became necessary, although no provision or easy method for increasing the station had been considered. The third time of construction a radical difference in ideas was introduced and without undue present cost, a line of increased capacity was forecast which will quadruple the capacity of the station whenever desired, by units of pumpage which may be made to extend thirty or forty years into the future; and this without materially changing the present building or entailing undue expense beyond the actual cost of added construction when the time comes, the building being planned on the unit principle and the plan made so flexible as to probably cover any possible modification in methods for pumping water in the future. If this look ahead had been made at first, a good deal of money would have been saved, and a good deal of trouble and inconvenience avoided. The first rebuilding would certainly have been avoided completely by a proper attention to possible increase. It is of course not the purpose herein to find fault about the matter, but it is the intention to point a lesson for future thought; the idea being that if something new and useful and economical can be learned now, put the past where it belongs, behind you, and start on a better road, NOW. The past is a valuable school house from which a great deal may be learned, but there is no room for regrets

in the busy field of water works construction and maintenance.

Make the most and the best of what you now have, and plan more wisely for the future; and in planning for the future do not try to utilize too much of old works about a pumping station, with a mistaken idea of economy. It is often cheaper to put up something entirely new, and when finished connect it to the regular establishment by a short and quickly made change, than to endeavor to rebuild and enlarge already existing buildings and intake accommodations. Sometimes unattractive concessions have to be made to accommodate changes in old structures and appurtenances, which would not be tolerated for a moment with a clear field in view. Do not be extravagant, but also do not be stingy in arranging for the growth of your pumping station.

In the early days of pumping engines it was not realized what the tendencies towards increase amounted to; or to what tremendous sizes the pumping unit would reach. But the view is clearer now, and there is really no good reason with all of the facilities at hand, for straying too far afield in search of the appropriate line to follow. Of course it is difficult to foresee what developments will take place for any very great distance ahead, but with the boiler item brought down so nearly to a scientific basis; with the analysis of coal for determining the amount of fixed carbon, and the possible number of heat units per pound so readily available; with a full knowledge of the heat possibilities demanded by the steam at the working pressure, and the actual capacity of the coal used to furnish the heat; the closely probable efficiency of the boiler to absorb the heat from the burning coal and transmit it to the forming steam; with a very clear perception of the laws of steam expansion and an extremely close knowledge of the slight remaining margin of work to be expected from the steam; with all of these items accounted for and the type of the most efficient engine practically fixed, it is evident that some most radical departure must be made in the science and art of generating and using steam, to defeat a well devised scheme of pumping station based upon what is so well known at the present time.

Water works people perhaps do not think enough of the future. Or if they do think of it, or their thoughts are turned

in the direction of what to expect, say, ten years ahead, the apparent expense, the necessary study of the subject, and the quantity and quality of the attention necessary to devote to it, makes, sometimes, perhaps often, too much of a mental load when coupled with their regular duties. It will pay, however, to go into the matter to a much greater extent than is commonly done, and an example is given below of how methodically the cost of plants built upon the unit basis may be determined. The table herewith given is sufficiently close for preliminary estimates; but conditions should be looked into carefully for exact estimates. In some actual cases the figures may be too high, and in other cases too low; but they are closely approximate and enough of them are based upon records to fairly ensure the table as safe for practical use. In fact, the table is so close that it would be taking chances for a contractor to guarantee the production of results for the figures named without investigating each case by itself. The work contemplated is for the best type of triple expansion pumping engines and high pressure boilers; a good design and quality of brick buildings, or of stone where stone is cheap; steel trussed and slate covered roofs; adequate chimneys; properly proportioned and thoroughly screened intakes. The cost given includes everything excepting the land.

TABLE.

Cost of Complete Pumping Stations.

Pounds pressure per square inch of the water load worked against.	Cost per million gallons of plant capacity, including a reserve.
30	$6,750
40	7,000
50	7,250
60	7,500
70	7,750
80	8,000
90	8,250
100	8,500
110	8,750
120	9,000
130	10,000

There are of course cheaper types of pumping engines, but they are necessarily of lower efficiency, and therefore requiring more boiler capacity, more coal storage, and other incidentals which, when balanced up, will tend to keep the figures about the same. A cheaper and less durable sort of building may be used, but in the long run this will need more repairs, which when capitalized will bring the account fully back to the above figures, and most likely exceed them.

It is scarcely possible that the cost of pumping stations for water works will be increased on account of a higher type of engine, because it is pretty evident that the top limit has been just about reached with the new record of a little over 181,000,000 foot pounds duty per 1,000 pounds of steam. Six years ago it nearly touched the 180,000,000 mark, and might have with some other refinement in the test, at any rate a gain of less than .6 of one per cent. in six years, with every nerve strained, is eloquent evidence of the top limit. The Mariotte curve is about the nearest approach to perfection in expressing the relation between the work done and the amount of steam used in doing it, apparently possible for the modern steam engine to accomplish; and, if the terminal pressure is taken as expressing the steam used and all of the steam is accounted for by the diagram; somewhere in the immediate neighborhood of 180,000,000 duty with 96% efficiency of the machine, will be the resulting figure, with a reasonable amount of steam used in the jackets and reheaters charged up against the account. If there were no necessity for the use of jacket steam the figure would approach 200,000,000 rather closely, and if superheating can save the jacket steam and vitalize the working steam, the latter figure may in the near future be reached so far as the report on high duty accomplished in a calculation is concerned, but if this pleasing result is obtained by a surface condenser with a consequently smaller air pump, although this type of condenser may require more maintenance account than the jet form, and if the superheated steam is obtained at the cost of coal; if these are so then, what's the use?

If the steam turbine or the gas engine can step forward at this stage of the performance and the growth of the pumping station, and show something better in the matter of water sent

up the hill in proportion to the coal bought and burned, it is now "up to them," to use a slang term which is fast gaining respectability, to do so. And this will of course effect a rather radical change in pumping stations so far as the buildings are concerned at least; probably so far as present evidence goes, however, the changes will be in the line of smaller engine houses and larger boiler and coal houses. Whether the cost of construction of the machinery itself will be materially less than the present record holder, when all difficulties are overcome, and the new era machine is what it must be to stay, time only can tell. The writer is at present carefully investigating the turbine proposition and its possibilities as a practical water works factor, is not yet ready to declare results, but hopes within the next year to be able to state its probable useful and commercial position in the field of pumping water for municipal supply.

Unless something very much out of the line of view at present develops in the near future, the ideal turbine pumping engine will be a turbine steam engine driving a turbine pump, all mounted upon the same frame, as there is a loss in developing power from heat by a reciprocating engine, turning it into the electric mode of motion, and then again changing this into the hydraulic form represented by water under pressure, the latter conversion being through the medium of a turbine pump driven by electricity. No reciprocating steam engine can live under the speed required for turbine pumps under the ordinary water head demanded by the average water works, so that direct connected reciprocating steam end and turbine water end are barred. The direct connected turbine at both ends of the machine has been used on a small scale with doubtful economy, but nothing calculated for the average or large work has been attempted, and of course that is where the greatest benefit lies. When it costs for coal $1,350 per year for each million gallons pumped per day, the total coal bill does not go very far into money for two or three millions of water per day, but when the quantity gets up towards, say, 10,000,000 gallons per day the figures are more important. The larger triple expansion engines both direct acting and crank engines, pump a million gallons of water per day with $625 worth of coal per year for the best records, and $900 is an ordinary

good record, while about $1,350 is the steam turbine pumping record so far as the writer can learn, and he is very anxious to know the truth, so as to be in the front rank when the turbine bears the colors. It looks as though the great struggle to keep down the capital account in the turbine outfit must be at least partially abandoned, so far as pumping water is concerned at any rate. If a high rim velocity is what the steam turbine needs, why not increase the diameter and reduce the rate of revolution so as to meet the demands of the turbine pump. The pumping of water is the main thing in a pumping engine, not the accommodation of a new fad in an old idea.

The gas engine as a water works motor is of course entirely undeveloped upon anything like the scale which it will have to reach to be seriously considered in fairly large schemes of water works pumpage. There will be found to be a great variation in the gas production from different kinds of coal, likely as much of a variation as in the generation of steam from different fuels. And this is not only from the difference in the coal itself but also from differences in gas producing apparatus. But development on this line is going on, and good results in economical and reliable gas production, easy of manipulation, will no doubt be one of the improvements of the future not so very far away, probably claimed to be already accomplished by interested parties. At the World's Fair at St. Louis, in 1904, there was an exhibition of a gas producing plant sending gas to a gas engine, which in turn was driving a large dynamo, and so a powerful electric current was produced with the burning of coal at one end of the system, with electric lights at the other end, just as we always see it, but with the boiler left out of the combination. This is a little hard on the boiler maker but then he can make the gas tanks for the future and at any rate just at present he need not worry about getting out of a job.

The large gas engines available for pumping for water works have not as yet come prominently to the front, and there are certain adaptabilities necessary to be made touching the matter of speed, for example, which complicates the problem more or less. There are many small pumping plants of course, where the gas engine fits in very well, but there are some incidental

items aside from actual fuel economy which have great weight proportionately in a small plant, but which would not be considered in a large pumping plant. The gas engine at its best can probably produce a horse power with one pound of coal, but this imposes conditions not favorable to the economical pumping of water under pressure suitable for water works stations. The record of 1.02 pounds of coal per indicated horse power hour is held right here in Boston by a pumping engine especially and completely adapted to the pumping of water upon a large scale. So you will perceive that the modern steam pumping station has already reached the apparent goal of possibilities in low coal consumption, quite as low as the gas engine can accomplish in actual service; the steam pumping station running generally from one pound per indicated horse power on tests, to a range in actual everyday service from 1.33 to 1.98 lbs. of coal consumed per indicated horse power per hour.

But the mere statement of the relation between various rates of efficiency in coal per power unit does not tell so much as a slight analysis of the factors. For example, confining for the moment the comparison to steam pumping engines, the writer has two records, one of 1.02 lbs. of coal per indicated horse power per hour, and the other 1.98 lbs. of coal per indicated horse power per hour, and both records obtained as nearly as could be under similar conditions in actual water works pumping. The fuel calling for 1.98 lbs. is slack at $1.50 per ton, and the fuel calling for 1.02 lbs. is anthracite coal at $4.50 per ton. The analysis of the coals for heat units on complete combustion was as follows:

Heat units developed by the slack.....11,000 per pound.
Heat units developed by the anthracite coal..14,000 per pound.

(These are approximate round numbers to make calculation easy.)

In the case of the slack the buyer obtained 146,000 heat units for a cent. In the case of the anthracite coal the buyer obtained 62,000 heat units for a cent.

The plant using the slack consumed 363 heat units per horse power per minute, while the plant using the anthracite coal consumed 238 heat units per horse power per minute. The efficien-

cy of the boilers was 70% in one case, that of the slack, and 80% in the other, that of the coal; and this reduced to work demonstrated by indicated horse power gives 13,200,000 foot pounds for a cent in the case of the coal, and 9,805,680 foot pounds for a cent in the case of the slack; with the efficiencies of the boilers equalized, and this of course shows that a difference of 3,394,320 foot pounds for a cent existed in the different economy of the two engines; a comparison between the duties per 1,000 lbs. of steam, and the foot pounds for a cent obtained in the two cases, show one to be a little above 30% and the other a little below 30% gain, which is near enough for a check.

A comparison between the two methods, one with steam and one with gas, shows that the steam pumping plant, and the gas engine with gas producer are just about on an equal footing, so far as producing an indicated horse power in proportion to the consumption of coal per hour is concerned; and this of course brings the matter between the steam power plant and the gas power plant down to the question of investment of money in the plant itself, together with the current cost of operation and maintenance. The gas power plant has not made sufficient records yet to enable us to determine very much in the pumping line upon a considerable scale, but whatever it will do in the future, it is perfectly evident at present that the steam pumping station has just about reached its economical limits in the best plants, although as yet only a small percentage of the plants in existence are enjoying the fruits of the advanced practice. The present high type of pumping engine can not be improved apparently to any material extent, so that the very best we can expect is an extremely small increase in economy by means of improved construction.

An increase in coal economy from 6% to 12% can most likely be gained by the use of superheated steam, although the interested and intelligent advocates of superheat will probably say that this is too low a figure for the gain. But it must not be forgotten that many of the good records for superheat have been made where engines of only fairly good economy are in use, whereas when the highest type of pumping engines are supplied with superheated steam, the application is then made to steam machinery of the very highest class, where multi-

expansion, steam jackets, reheating, etc., are used to reduce the internal losses and condensation to an extremely low point. As already pointed out, very nearly the possible limits have been reached in utilizing the steam in modern pumping engines; the jacket system has been modified somewhat from early practice, and so brought to a high state of efficiency by keeping the heat in the jackets very closely to the balancing point, where the greatest good will be done with the least loss from useless radiation within the cylinder; the distribution of the steam is now very satisfactory and perfect, and the waste room or clearance is brought down to surprisingly low terms by the better arrangements of valve gear and steam ports.

If there is any waste heat in the smoke flues of the boilers, of course re-heaters for the receiver steam can be provided, and this steam made a vehicle for the transportation of the heat now getting away up the chimney, back to the engine, and made to do work there. This is no special credit to any particular type of engine beyond presenting facilities for the use of such heat as the boilers are allowing to escape. But it will reduce the coal bills by turning into useful work some of the heat of combustion unabsorbed by the boiler heating surface. It is not entirely clear why more of this practice of flue reheating has not been done. It certainly has been long enough known. The writer has now before him a supplement of the *American Machinist* of October, 1878, illustrating the Pawtucket pumping engine designed and built by Geo. H. Corliss, in connection with which flue reheating was very successfully used, the duty given by a small cross compound engine reaching the very satisfactory figures of a little over 133,000,000 ft. lbs. with 100 lbs. of coal. Within the last five years the Barr Pump Company used this device at Heverhill, Mass., also in connection with a moderate sized cross compound pumping engine, and the very best of authority reports over 150,000,000 ft. lbs. duty per 1,000 lbs. of steam, which at 9 lbs. evaporation, a fairly good figure for boiler work, would amount to 135,000,000 ft. lbs. per 100 lbs. of coal. The question plainly is, why in the growth of the pumping station has this sensible and easly applied auxiliary not been more utilized?

The quadruple expansion pumping engine with an additional steam cylinder, resulting either in a tandem arrangement for a portion of the engine, or an abandonment of the very desirable three plunger scheme, so favorable for steady hydraulic effects, has no great future before it, and even if it had, there is no good reason for making material changes in the station buildings, for it will of course be a vertical machine when the present day units are considered, and will likely occupy no more floor space. But likely it will never come at all to any great extent, for, with the 33 to 40 expansions practicable with the triple machinery possessing such admirable mechanical lines, and with the conversion of heat into work about up to the limit, there is in fact no room for the quadruple expansion machine. Some people not specially familiar with the matters pertaining to pumping stations rebel at the idea of even going away from the compound engine, and scout the idea of tripling a machine, but basing their notions strictly upon, to themselves, unknown quantities. The distribution of water into a force main from three plungers has never been surpassed and likely as not never equaled, and in addition to that fact, and in the face of a good deal of talk, the triple engine holds the economy record far ahead of compound machinery.

By looking backward over the road travelled during the last twenty years of growth of the pumping station, it will be readily perceived that the demand has always been for a higher and higher class of pumping engine, and as the reduction of the fuel expense became more and more of an object and more and more clearly possible, and there was a better understanding of the whole subject, the engineers and the men who pay the bills were brought closer and closer together, until to-day, it is surprising to see what a high type of machine has been produced for a price which in the past would have been considered simply ruinous to the builder. In the old days the competition was between machinery at a low cost, but consuming a considerable quantity of steam and coal; and machinery at a high cost consuming a comparatively small quantity of steam and coal. This, of course, brought the fuel and interest accounts into antagonism, and in many cases the most economical lines, all things considered were worked out, the

consideration of size and cost of buildings not infrequently coming into the controversy. The Worthington pumping engine, in 1878, fairly held the front line in the form of a direct acting, non-rotative, compound condensing machine, and in many cases successfully disputed the field with the many odd and unrepeated forms of the crank and fly wheel pumping engine, forging at that time to the front bearing the standard of a higher steam economy. For a good many years the direct acting engine as an all around better proposition held sway, and for durability and reliability as a machine for pumping water for public supply has never been excelled. But gradually the financial end of the crank and fly wheel manufacturing establishment and the engineering end drew closer and closer together; then the Worthington engine took on a high duty attachment and the competition went merrily on. The problem was to reduce the capital account by simplifying the design, and keep on raising the duty; at least simplifying the design of the crank and fly wheel engine, and a task very effectually done by Edwin Reynolds of the Edw. P. Allis Co. In other words the problem was to maximize the efficiency, minimize the cost, and maintain the durabilty at the high level of the Worthington mark. The two former have been accomplished, but when we see one of the old time direct acting pumping engines plodding along after over a quarter of a century of hard work, and apparently in good health and spirits, we are not quite ready for a vote yet on the last of the three counts given above. Still the latest types of the crank and fly wheel machine are doing very well, and the commercial points seem to be very well met in many cases, all things considered.

When the possibilities of water works pumping began to attract broader attention, and it began to dawn upon the minds of those interested in the production of such machinery, that the growth of cities, the increased demands for water pumpage regardless of what became of the water, and the increase in the size of the pump units, demanded a higher economical type of machine, many attempts were made to retain the simplicity and low cost of the direct acting engine and at the same time secure the saving in fuel incidental to a higher steam ex-

pansion. But the presence of an obstinate fluid demanding steady propulsion at one end of a machine, and the use of a highly expansive fluid demanding tremendous differences between initial and terminal pressures to secure economy, at the other end of a machine, put designers to their trumps, and a long line of unrepeated failures ending with increased complication in the perfected machine, seems to be the best that can be shown by the record.

So far as the types are concerned, the growth of the pumping station has finally resulted in but three pronounced types of pumping machinery, the construction of which has been repeated enough times to make them really distinctive. These are as follows:

The Worthington High Duty Engine, both vertical and horizontal.

The Gaskill-Holly Engine, horizontal.

The Reynolds Vertical Three Plunger Engine.

Some cross-compound engines are built, but they can hardly be called a type, although in the horizontal form they make a very good engine. In the vertical form with the cranks at 180 deg. the engine does very well for reservoir work, but is extremely objectionable for anything like direct service, or where the consumers can feel the pulsations certain to be set up where the pumping column is cut off completely, twice at each revolution, and without any blend of delivery of any sort. In the horizontal form the 90 deg. crank engine is unobjectionable, and answers well even where consumers are involved. But the cross compound vertical with 90 deg. cranks, should be shunned by all hands.

On direct service, with a system of closed pipes without storage, the cross compound would not be quite so good as the Gaskill-Holly engine, on account of the variations constantly taking place in the demands and consequently speed and power, and although the reasons for this are perhaps of too technical a nature to be embodied in a general water works paper, belonging rather to papers dealing with engineering strictly, the writer will go far enough to say that any changes in power in the cross-compound engine varies the relation between the work done in the high and low pressure cylinders

at opposite sides of the engine, and so destroys more or less the economy and regularity of the engine at work under a variable water load, and a load which varies the speed as well as the power, quite contrary to the variations in the work of a mill engine where the speed is practically constant. With the Gaskill-Holly pumping engine each side of the machine is a complete compound engine and whatever variation one feels the other feels as well, but without interfering with the relations between high and low pressure cylinders at opposite sides of the engine; each side taking and using steam and exhausting it into the condenser independently of the other side. The crank shaft simply keeps the pumps in proper relation to each other with reference to the water column, and this pumping engine in general design and under good construction is probably the best machine ever brought out for direct service and closed circuits of pipes without storage.

The Worthington Horizontal, High Duty, Compound Engine works well on direct service, but attempts to regulate it automatically have been little made, in fact, not much needed, as the compensating cylinders receiving their pressure practically direct from the water load, although through the medium of an accumulator, respond very readily to changes of pressure and speed.

The Reynolds vertical three-plunger engine has not been much used on direct service probably for the reason that this engine is generally used in large units, in systems too large to be really classed as of closed circuits, or mostly used in reservoir service. In an extensive system of pipes such as are used in the larger cities, even if there is no reservoir, as in Chicago, to pump into, there is a certain elasticity inherent in so many branches and outlets which furnish a constant relief and demand, quite the equivalent of a free delivery from the force main into a reservoir a long distance away from the machinery.

The growth and drift of the public pumping station seems to be towards larger and larger units, and the vertical triple expansion engine. Not only larger engines, but also towards smaller triple engines and we begin to be accustomed to seeing 6,000,000 and even down to 5,000,000 triple vertical engines in operation. Just what the next ten years will bring out in the

further growth of the pumping station can not of course be definitely stated; it looks extremely doubtful for the dominance of the turbine type in that time, if at all, and the gas engine has not yet really made a good start for the front line. Superheated steam and generally higher steam pressure up to about 175 lbs. will probably take place, gradually, and that will likely be the last firing line of the reciprocating triple expansion pumping engine. It will hold this line stubbornly, and it will require a great deal more progress than is evident in any direction at present to dislodge it or even shake it materially. Its capital and fuel accounts even with coal at a moderate price make a very satisfactory showing just now, and the maintenance in the presence of good design and construction will not exceed 2 per cent. in good sized or moderate plants where it is reasonably cared for. Therefore it looks fairly safe to plan away for another generation at least, and look out for the future units during the remodelling of old plants or the construction of new ones, and the perfect plant so far as present evidence goes, will involve the following items:

Water tube boilers.

Mechanical stokers.

Natural draught at least .8 of an inch of water.

Feed water economizers.

Damper regulators.

Coal bought on the basis of 14,000 heat units per pound.

175 lbs. steam pressure per gauge.

Moderately superheated steam by independent apparatus.

Modified steam jacketing and re-heating.

Smoke flue re-heating.

Vertical triple expansion pumping engines of long stroke.

200 feet per minute piston travel maximum.

20 revolutions per minute maximum.

Coal per indicated horse power hour, 1 lb. for large plants.

Coal per indicated horse power hour, 1.75 lbs. for small plants.

Maintenance of engines, 1.5 per cent. for large plants; 3 per cent. for small plants.

These and some other items of similar nature are about what a look ahead discerns as the coming events in the planning, construction, and operation of pumping stations for public water supply.

MR. MAURY: I had not intended to say anything in discussing this paper except to express my appreciation of the honor done the Society by giving it to us. I am afraid I must take issue, as I did last year with some of his conclusions. I wish to repeat what I before said that there is no question of one of these types of engines absolutely superseding the other for all conditions, because each will continue to have its field; but I do think that perhaps Mr. Hague has not made his comparison of the relative economies and relative advantages of the two types on what might be considered more general ground. I rather think that he has taken the field which is perhaps more advantageous for his side of the discussion.

MR. H. F. DUNHAM: The speaker does not propose to discuss special features of pumping machinery with the able author of this paper; but in the very title of this paper the author includes a factor no less important than the growth of cities and then fails to make any reference to it afterwards. That factor is the management or the character of the management of the water works plant—the "broad-cast" water works of course not one of those represented here. The growth of the average station as indicated by the demand for additional machinery cannot be looked upon with great favor or satisfaction. The reason for this is that the management is lax. Where this condition exists, where water is allowed to go to waste in large volume through poor mains and fixtures, where flush tanks for sewers are allowed to fill and empty forty or fifty times per day, where water goes broadcast from the pumping station and where every extension is made with small pipes, it will be found that the station has not sides enough for extensions for boilers, for compressors, for pumps, condensors, etc. Nor would it have if the ground plan of the building had been a hexagon. On the other hand, having still in mind the average station, if the management were to become thoroughly good and the quantity of water supplied be reduced to fifty or sixty gallons per capita, existing machinery might very well serve for a period of years and then require but modest additions.

A feature so important as this, and one that is daily becom-

ing more important as water of better quality is demanded, should hardly be overlooked in a paper with the broad title —"The Growth of the Pumping Station."

The rule mentioned in the paper as a rough one, does not appeal to the speaker. The author of this paper has just read and approved another paper containing a number of tables. According to these tables, let a station supply four thousand people; then two engines of three million gallons capacity each would be required. Now, if the author's rule were to be followed, the right thing as the population in that city increased would be to put in a six million gallon engine, giving a total capacity of twelve million gallons. That happens to be the capacity which the table provides for a city of 25,000 people. Why should the small city, when it has a population of little more than four thousand, be burdened with the amount necessary to provide for the wants of a city of twenty-five thousand? If it were a question of greater safety, there would be good sense in it, but the six million gallon engine may be out of repair for weeks and in no city of such proportions should one-half of the total capacity be out of repair at any time.

The present tendency is toward more economical machinery, but, referring again to the tables, it is evident that the six million gallon pumping engine would have to be kept for fire protection service alone, or for a long time operated at about one-sixth of its total capacity. This introduces a condition little, if any, more favorable to economy than those set up at the installation of the plant.

The speaker believes a good rule for the average case is to have one or two economical units of a capacity to deliver the daily domestic supply and other units of such size and number that the failure of one will not cripple the fire protection.

Mr. F. A. W. Davis: I did not expect to have anything to say in regard to pumping engines, but as the question has come up in the shape of the type of engine and the boiler, it seems to me that there is another engine that we may consider, and that is the Diesel oil engines that are being introduced with very satisfactory results.

So far as the Gaskill engine is concerned, we have one that was among the first ever built by Mr. Gaskill, and it has proven successful. In regard to the twenty million gallon engine of the Snow type, Mr. Reynolds, after the engine was erected and tested, came to the City of Indianapolis and made a study of the engine, and his opinion as expressed to our engineer was that they had been building their engines with too small valve ports.

Coming back to the testing of an engine, that is the most important feature that is connected with an engine. How are we to do it? Some of us have direct acting pumping plants. If a man has a reservoir, that is possible; but when you make a test of an engine you must do it under business conditions. Your engine cannot be stopped and shut off very well to make those tests, and while being operated it is of course being run at irregular speeds by reason of the large openings on the mains. It is a very difficult problem for us to settle what is the economy, efficiency and duty of an engine. If you could put it at normal duty and make a test of it under proper conditions you would then get some idea of the value of the engine as an economical engine; but we find difficulty in doing that. It is not possible to build an engine capable of running economically at all speeds. At midnight you may be pumping at the rate of four million gallons. During the day you may be pumping at the rate of twenty-five million gallons. So that makes it hard to ascertain the duty of an engine.

Another problem is how to measure the discharge. If we could put up a weir and weir it, we could get an idea of the capacity of the engine and its duty; and that perhaps is as good a way as any. We all talk about putting them under a high pressure; but that is a difficult problem. So in considering whether we are going to use a turbine engine, a Diesel engine, a gas engine, or a reciprocating engine, we should be careful before changing our ideas from the ordinary slow moving high duty triple expansion engine.

Secy. Diven: I want to say a word for that old friend of mine, the sixty-five million gallon duty engine, which I believe has its place. Take a small plant where the engineer is also the fireman, makes out the bills and tends to other duties, an

engine like that, that he can start up and go off and leave until he is ready to come back, when he will find it still going, is a pretty good engine for a works too small to employ expert attendance.

MR. CROWTHER: (by letter). It is the day of economies in operating expenses. Everywhere the aim of the business manager is to cut his costs; but while the reduction of cost in manufacturing industries has received particular attention, expenses in other directions, including that of pumping, have not had the same consideration.

There is no reason why this should be so. The cost of pumping water can be greatly minimized, especially since the gas engine has assumed its present position as a prime mover. With a theoretical and practical efficiency of from two to five times greater than that of the average steam engine, it scores heavily in the important item of economy of operation; and, in connection with a gas producer, it eliminates all stand-by losses, and reduces the cost of maintenance and repairs very considerably below that of the steam engine and boiler. It is no longer necessary to install large reciprocating pumping engines with intricate detail, together with boilers and stack. The gas engine has changed all this.

Coupled to a centrifugal pump, it is the ideal form of pumping water or other liquid. With a gas engine yielding a thermal efficiency of from 20 to 25 per cent., and a gas producer developing one horse power per hour, upon one pound of coal, it can readily be seen what economies can be effected. In a gas producer plant recently tested, with anthracite culm as fuel, the cost of fuel per horse power was about 1.5 mills. From this it varies, depending upon the cost of the fuel, but in general it may be broadly stated that the fuel consumption in a steam engine is from three to five times that of a gas-driven unit, fired by producer gas. For large units—from 2,000 h. p. upward—it is possible to introduce by-product recovery, which will enable the gas for power purposes to be delivered to the engine practically free of cost. In other words, the sale of the by-products will in many cases offset the cost of making the gas.

Thus the centrifugal pump—in itself a cheaper proposition

—can be linked to a power unit that offers many advantages, among which are the following:

No standby losses;
No smoke nuisance;
Lower first cost;
One-fifth to one-half cost of operation of steam plant;
Lessened depreciation;
Reduced repairs;
Smaller floor space.

In the matter of depreciation and repairs it is sufficient to cite the gas producer-gas engine plant of the Erie Railroad Company at Jersey City, N. J., where the producers have been in use for nearly eight years, and have not yet required relining with fire brick; whereas, had these been steam boilers the expense of this item alone would have been heavy. In one of these producers the fire has never been out. Imagine a boiler after such a run!

At the St. Louis Exposition in 1904, the United States Government installed a coal testing plant. As indicative of the value of the gas producer the following extract from the preliminary report of the U. S. Geological Survey is submitted:

"It will be necessary to test a larger number and greater variety of coals and lignites, and to repeat with greater care some of the tests already made, before a full discussion of the results of these investigations can be properly entered upon or their value fully appreciated. But the results already obtained from the preliminary investigations made during the last six months are sufficient to indicate their far-reaching importance in the solution of the fuel and power problems upon which the varied industries of the country depend.

"Most of the American bituminous coals and lignites can be used as a source of power in a gas-producer plant.

"As indicated by comparative tests of 14 bituminous coals from 9 states, the power efficiency of these coals when used in the gas-producer plant is two and one-half times greater than their efficiency when used in the steam-boiler plant; or, in other words, one ton of these coals used in the gas-producer plant has developed, on a commercial scale, as much power as 2 1-2 tons of the same coal when used in the ordinary steam-boiler plant.

"The value of the results of these investigations is, of course, not limited to the coal-producing sections of the country, but extends through every state and territory where coal or other mineral fuel is used as a source of power. Thus, in the New England States no coal is mined; but in the year 1900 the steam power produced through the consumption of coal and used for manufacturing purposes in these States cost approximately $50,000,000. The development of this power through the more efficient methods suggested by these investigations would mean a saving to the manufacturers in these States of $15,000,000 to $20,000,000 per annum.

"As another illustration of the way these investigations may influence the affairs of the nation as a whole, it may be stated that there were used in the naval vessels of the United States in 1903 approximately 500,000 tons of coal, costing $2,500,000. If the future gas producer and gas engine can be substituted in our battleships and cruisers for the existing steam boilers and engines, the saving in the cost of coal would be not less than $1,000,000 per annum, or, what would be of far greater importance, the distances traversed by each ship without coaling would be more than doubled."

It is, of course, in some cases undesirable or prohibitive to use producers. In this event either natural or illuminating gas can be utilized as fuel for the gas engine—driven pump; or a motor-driven centrifugal pump, which can be installed in numerous places, run by current taken from an adjacent trolley or lighting line, will in many cases solve the problem of a centrifugal pump for any purpose, especially since the recent development of the latter for higher pressures has materially reduced the cost of such installations, both as to machinery and buildings.

In the smaller cities and towns throughout the country the authorities are awakening to the fact that all places that have not already done so must, within a reasonable period, install water works and sewerage systems. Both are demanded as necessary adjuncts to civilization, and the problem is easy of solution to-day. A single-stage or a series compound centrifugal pump, direct-connected to an engine or motor, can be housed in a small building and take power from any available

source, thus settling the water works' problem for many towns at a low initial cost as compared with a steam-driven reciprocating pump.

And while the centrifugal pump is finding a large development in the smaller towns for Water Works Systems, there is another field in the larger cities for which it is pre-eminently adapted. This is the field of High Pressure Fire Service.

No more important problem confronts our municipal authorities than that of furnishing adequate fire protection—especially to business districts in the large cities. It is an engineering problem that is being forced upon public consideration by reason of the enormous losses in those districts incurred by insurance companies, which ultimately react upon the public in the form of increased insurance rates.

In New York, Chicago and other of the American cities many office buildings approach or exceed a height of 300 feet, this altitude imposing at the start a head of approximately 150 pounds per square inch, in addition to that of friction; and the present type of steam engine is not adapted to present and future requirements. It is not sufficiently elastic, and above all, too much valuable time is lost in getting a stream upon the fire. This is vital, for the first few minutes of a conflagration almost invariably determine its extent. To bring it under control with the least possible delay is the object to be attained in all cases, and nowhere is this more important than in the crowded wholesale and manufacturing districts of cities, the contents of whose buildings are usually composed of those articles of merchandise that could not better feed a fire if especially designed for that purpose.

Under such conditions the obvious remedy is an independent high pressure pipe system, receiving its water supply from a conveniently located central pumping plant, and provided with numerous hydrants suitable for the direct attachment of the heaviest hose lines and without the intermediary fire engine. With such a system individual buildings equipped with stand pipes can be constantly connected to the fire system and kept under pressure. With such a system, having high pressure constantly maintained in the water mains, all that is necessary to do is to turn on the water—it being of course understood

that apparatus for properly directing this upon the fire be instantly available. This plan, of course, invoices special pumping stations for maintenance of the pressure.

New York has recently appropriated several millions of dollars for high pressure fire service, in this instance drawing salt water directly from the East River, and a number of other cities have also either determined upon the installation of such plants or are preparing to do so. In Philadelphia the high pressure fire service has been in practical operation for some time; and since it has been in use in that city there has been no destructive fire in the wholesale section which it covers. Several conflagrations have occurred during this period, but without exception they have been brought promptly under control in a space of time that was impossible under the old methods, and which has undoubtedly prevented serious results. The success attending the Philadelphia high pressure system is well known among the engineering and municipal authorities interested in its development.

It is not too much to say that the centrifugal pump, while it may not revolutionize the pumping field, is going to be very much more of a factor in the next few years than it has been in the past. The trend of the times, in matters mechanical, indicates unerringly a movement from the reciprocating toward the rotary type of machine—whether this be turbine, motor, blower, or pump; and not among the least of these will be found the centrifugal pump, with its low initial cost, comparatively small repair charges, greater durability, and high pumping elasticity.

Mr. French: One point that Mr. Davis has brought up may be of interest. He mentioned the difficulty of testing by weir, especially in cases where it is desirable to test your pump at high pressure of discharge, probably the same pressure that the pump ordinarily works at. We have done a great deal of testing work with a large nozzle connected up directly to the discharge main and with the pressure taken quite accurately behind the nozzle, a few feet probably, which will give us an accurate measurement of the quantity of water discharged. It is feasible to use that method with nozzles of 2-inch, 4-inch, 6-inch, 8-inch and up in size, and get your

quantities within one or two per cent. That method is much less cumbersome than a weir, and can be readily made a permanent part of the plant by connecting the nozzle and letting it discharge into some suction well, or through an outlet. At intervals, periodically, the pump can be simply run and discharged through that nozzle, and the engineer can thus ascertain in a few minutes whether the pump slippage is excessive and whether everything is running all right. In a good many cases the nozzle would give a very ready means of doing all that is necessary, and would be a very valuable part of the permanent equipment of the pumping station. The cost is very light. The whole theory and investigations of the nozzle test will be found in a paper by Mr. John R. Freeman, which was, I think, printed some years ago by the American Society of Civil Engineers.

PUMP SLIPPAGE.

By Alba L. Holmes.

We know that if a pump is in good condition that it should deliver within two to five per cent. of its rated capacity, and probably for this reason Engineers and Superintendents have continued to hold to this rating for slippage even though the pumps may be old and perhaps have not been examined inside for a long time.

I find in very few reports allowances made of more than five per cent. for the slippage of pumps from the tally of the engine counters while there is a marked difference in the conditions under which they work as regards lift of suction, pressures on force main, character of the water in regard to grit, purity, minerals and other things.

We have started our computations of per capita consumption upon the records of our engine counters and have based the cost of fuel to pump a million gallons upon the same foundation. We have criticised the efficiency of the water meter, on our factories and domestic services, comparing them with the results at the pumps which we have taken as correct. We have sort of drifted into this condition, as the operations of the pump are largely concealed from our view, and we have acted on the old saying, "out of sight, out of mind."

In another manner we have overrated the capacity of our underground water supply in many instances, and that is by citing the pumping records from wells computed by strokes of the pumps without considering their efficiency.

I find by personal inquiries among Engineers and Superintendents that the actual information upon this subject is meagre.

But in all of the records of actual tests that I have obtained, the slippage is much more than we have allowed, and I think that we should consider well Davy Crockett's idea of being "sure that we are right before we go ahead" with statements of the amount of water pumped per capita.

It is not my intention to write a long article upon this inter-

esting subject, but to place before you the results of the tests made for slippage in a few of the plants of the West, notably the smaller ones, with the hope that it may induce others who may have charge of plants to investigate this point and give the association the results of their researches.

To show how some of our prominent engineers look at this question, I quote from a few of the many letters that I have received in regard to this matter in the last year.

Mr. Dabney H. Maury, C. E., of Peoria, Ill., writes that he has measured the slippage on a number of small pumping engines showing a slip of from 15 to 80 per cent., and that on one large engine eight years old and in use about four years; he found the slip 3—65/100 per cent. In conclusion, he says: "I agree with you entirely in thinking that the usual plan of estimating pumping by plunger displacement is liable to be very much in error."

Prof. M. E. Cooley, Dean of the Department of Engineering of the University of Michigan, writes me along the same lines, and in closing, says: "We have planned our Hydraulic Laboratory to do some very accurate work along these lines. We have two weighing tanks of 600 cubic feet, arranged to receive our discharge from various sources including pumps. We shall hope later on to give you exact information on two or three types of pumps at least."

Mr. W. G. Kirchoffer, C. E., Madison, Wis., writes me that by tests made at Waupaca, Wis., he found the slippage of the old pumps from 25 to 50 per cent., and one of them very much more, and says in conclusion, "You really cannot tell anything about what you are doing without gauging the water or a meter."

Prof. H. K. Vedder, Professor of Civil Engineering in Michigan Agricultural College, was unable to give me much actual information, and says: "I have made tests of rather ordinary pumping machinery, where the slip did not exceed eight to ten per cent.," and further says, "that a slippage of more than ten per cent. needs attention."

Mr. Arthur S. Tuttle, C. E., of New York, has given me some valuable information along these lines, and cites actual tests made in that city during 1904 and embodied in the report of Messrs. Burt, Hering and Freeman.

The crank and flywheel outside packed pumps offer less chance for error than perhaps other machines, but the popular impression that it has no slip is not verified by tests of machines in use for some time. While the leakage at the packing point is taken care of, yet there are loose valves, broken valve stems and springs, valves held up by pieces of stone or sticks and other things that happen in real life.

But the majority of the pumping engines in our smaller towns are not of this type, and it is the exception that I find a machine of the duplex pattern that continuously makes the full stroke, although the displacement as recorded by the engine counter is for the full capacity of the pump.

The pump builders are not to be criticised for this discrepancy in measure, for they build right, and it remains for the users to keep them so by constant care and watchfulness.

I have the result of tests upon a flywheel inside packed pump of 1½ million gallons daily capacity, made by Mr. Clarence W. Hubbell, Civil Engineer for the Water Department of the City of Detroit, at Saint Clair, Mich., showing a slippage of 47 per cent., although the pump was considered to be in fair condition.

Mr. Hubbell also made tests upon another pump of the same make and size in the Water Works at Grosse Pointe, Mich., showing a still greater slippage.

A duplex pump of the same capacity in use at Charlottesville, W. Va., tested by Mr. C. L. DeMott, C. E., of Lynchburg, Va., pumping to a tank, showed a slippage of 47 per cent.

At East Tawas, Mich, I found a small duplex pump, with 8 inch by 12 inch water plungers, supplying the town at 18 strokes per minute, but with the gate closed on the outlet force main, the pump still run at 8 strokes per minute.

Tests made at South Bend, Ind., by the Pitometer Company, upon three power pumps of the Flanders make which had been quoted by the Department as pumping three million gallons daily showed that they were actually pumping less than half that amount. After being thoroughly overhauled and repaired they still showed 10 per cent. slippage. These pumps are fitted with large valves not used in up-to-date machines.

Tests at Columbus, Ohio, on two 5-million gallon pumps

showed that only two-thirds of the water recorded by the counters actually passed into the force mains, and the same results are recorded in other cities where accurate information can be obtained. If the facts were known, we would find that it takes more coal to push a million gallons of water into our reservoirs or mains than the reports indicate.

At Holland, Mich., as reported to me by Mr. James De Young, Superintendent of Public Works, an electrically-driven triplex 3-million daily capacity pump showed by counter a large increase in its delivery, which investigation, after a good deal of delay and trouble, located in a broken piston head, and showed that one-third of the recorded water never left the pump.

This is only another bit of evidence that this matter of slippage is not confined to any particular type or make of machine, and I do not remember an instance where I have seen a pump opened after continuous use for any length of time, without finding something wrong with the valves or packing.

Tests made at Chicago in 1904 by the Pitometer Company show in part as follows the slippage at the various stations:

68th St. Station	11.7 per cent.
Lake View Station	11.8 per cent.
Lake View Station	8.3 per cent.
West Side Station	20.7 per cent.
22d St. Station	28.5 per cent.
Central Ave. Station	2.9 per cent.

The following extracts are from the Report of the Commission on Additional Water Supply for the City of New York made in 1904 by Messrs. Burr, Hering and Freeman.

"Engines Nos. 1, 2, 3, and 4, in the 179th Street station have been running in regular service as the consumption required since 1897. The cost of repairs during this entire period is reported to have been remarkably low. On the 1st of May, 1903, in co-operation with Mr. N. S. Hill, Jr., Chief Engineer of the Department of Water Supply, Gas and Electricity, these engines were thoroughly overhauled and found to be badly in need of repairs. Tests made May 8th on the pumps showed excessive slippage or loss of action, caused principally

by water valves adrift, which amounted to 60 per cent. on pump No. 2, and 65 per cent. on pump No. 4. These slippage tests were made by taking the revolutions, steam and water pressures when the engines were running in regular service, and afterwards the same data with the engines operating under the same conditions in regard to steam and water pressure, but with the gate valves on the discharge main closed. After each test the manhole plates on the pumps were removed, and the openings from the discharge pipe into the pumps were inspected to detect any leakage past the gate valves. In both cases the gate valves were found tight. To determine the slippage through the pump valves and past the plungers, the displacement of the plungers represented by the revolutions of the engines while the gate valves on the discharge pipe was closed, was taken.

SLIPPAGE TESTS.

	Data before repairs.		Data after repairs.
	Engine 4. May 8.	Engine 2. May 11.	Engine 4. May 11.
Rev. per min. in regular service, gate valve on discharge pipe open	30	30	30
Steam pressure at engine, lbs. per sq. inch	150	150	150
Water pressure by gauge on engine, lbs per sq. inch	45	45	45
Rev. per min., with gate valve on discharge pipe closed	19.5	18	1.25
Percentage of loss of action or slippage	65	60	4.16

It is almost inconceivable that the pumps could have had their valves in this inefficient condition for a long time without discovery.

An attempt was made to analyze the record of average pumping as reckoned by plunger displacements for several months previous, but its incompleteness and doubts concerning its accuracy prevented.

Pumps on Engine No. 4 were repaired first. To show the simple nature of the repairs it may be stated that the work was begun on May 8th, finished and pumps started in regular service May 11th.

On account of the necessity for continuous running it was considered by the engineer in charge that Engines 1 and 3 could not be stopped for a detailed test. They were, however, examined and repaired, and no indication of such excessive slip found as on Nos. 2 and 4. Several of the small pump valves were, however, missing on each engine. It was, therefore, assumed that Engines Nos. 1 and 3, after the repairs, had only 4 per cent. slip, like Engine No. 4, but that prior to the repairs the slip was somewhat greater.

The best practical test is found in the fact that two of the engines previously run were shut down after the repairs. Prior to the first of these tests, five engines, including the new engine No. 6, were kept in operation in the 179th Street station and one engine in the High Bridge station in order to supply the consumption. After the repairs were made on all pumps it was found that because of the prevention of slippage, one engine in 179th Street Station could be shut down all the time, and the engine at High Bridge Station could be shut down the greater part of the time, while the remaining four engines, including the engine No. 6 in 179th Street Station, performed all the work previously performed by the six engines."

These tests show that in cities of the first class, this question is of as much importance as in the cities of five, ten and fifty thousand, and that, while perhaps the larger cities claim to employ better engineers at a higher salary, the results are no better, and that some means other than the revolution counters now in use on pumping engines should be employed to show the actual amount of water pumped.

I do not need to point to the remedy for the troubles and inaccuracies that I have shown, but hope that the few facts cited will stir the members of this Association to endeavor to find out in plants under their charge, how effiecient their pumps are and how much of the value of the fuel is used in actual pushing of water through the mains.

This may also have some bearing on the much mooted

question of how near the domestic and factory meter comes to telling the truth about the amount of water used in a wholly metered plant, and give a reason, other than the inaccuracy of the small meter, for the discrepancy between the pump record and the records of the water meters.

Pump slippage is responsible for a good large percentage of the cost of fuel and loss of pressure in our water plants. It is an important factor in the efficiency of the fire service and its correction is along the lines of economy, which should be the watch-word of all water plants.

Eternal vigilance is necessary to secure satisfactory results.

Discussion

Mr. William Perry: This problem of pump slippage is, I think, a matter that requires considerable attention from water works men. I have had considerable experience in that matter. Only a short time ago I was called to make a test of a plant a short distance from Montreal. The pump was running at the rate of 50 r. p. m. With that pump we could use only 2-inch streams, ineffective for fire purposes; and the engineer in charge said, "There is something the matter with my pump. Everything else is all right. I cannot see why we do not get the water." We shut off the valve leading to the main, and where the pump ran 50 r. p. m. before we closed off, with 80 lbs. water pressure and 75 lbs. steam pressure, with the valve closed off we made 18 r. p. m., and the water passed between the piston and the cylinder. The upshot of it was that after making the pistons tight we could throw three inch and a half streams and had good fire service. It shows that there was a loss by slippage in that one pump, not only of coal which had been used to get steam, but in efficiency in fire service. In another case a pump ran just as well with the valve closely made as it did with the valve open; but there was nothing the matter with the pump, it was all right. When we took off the water end the water spurted from one side to the other. I saw where the difficulty was.

As a general thing when you have slippage in a pump the first thing to do is to see if the lower valve of the pump is tight; close off the gate leading to the mains, put 150 lbs. water pressure on the steam pump side, and you can then very easily distinguish whether the water is coming between the piston or plunger and the cylinder. In that case, we had measured the water, and had even gone so far as to weigh it. We found from 1 1-2 to 70 per cent. of water passing between the cylinder and the piston. We have had them so tight sometimes that running just to get water they would stick, get warm and expand so that they would not move at all. Therefore it is plain to me, and I think evident to water works men generally, that the first requisite is to look more carefully into the interior of the water end of the pump. There is no doubt in my mind from practical experience that coal is burned right

along from day to day where pumps are slipping water backward and forward.

A case came up where we had 40 lbs. pressure in a 4-inch main, in a small town. The hydrostatic pressure was 40 lbs. When we opened the hydrant, with a 1-inch nozzle we had 4 lbs., which shows that the water was passing between that cylinder and the piston. I think, gentlemen, this is something that should be taken up more fully by many water works men, so far as pump slippage is concerned. In England I saw an account of a test the other day where they had leather cups on the piston, a brass lined cylinder, and the slippage was not 5 per cent. They ran six months without any change. I hope my remarks will meet with your approval.

Mr. Hague: Mr. President and gentlemen of the Association, some of these statements are appalling as to loss through pumps, and it seems to me that there must be something very serious the matter when the percentage gets up to the figures given in the paper. It reminds me of a story told of the examination of an applicant to run a steamboat. He passed the usual examination very well, but finally one of the commissioners wished to test his capacity, and he said, "Suppose the water was going down in the boiler and the feed pump was not throwing any water, and you looked over the side and there was not any water there, what would you do?" "I would tell all the hands to run for their lives and those that could not run to stand by, and there would be a devil of a—" (The rest of the sentence was drowned with laughter).

It seems to me that when slippage gets up to the 10 per cent. limit and to some of the other per cents. mentioned in this paper, they either want to change crews or else get a new superintendent of water works.

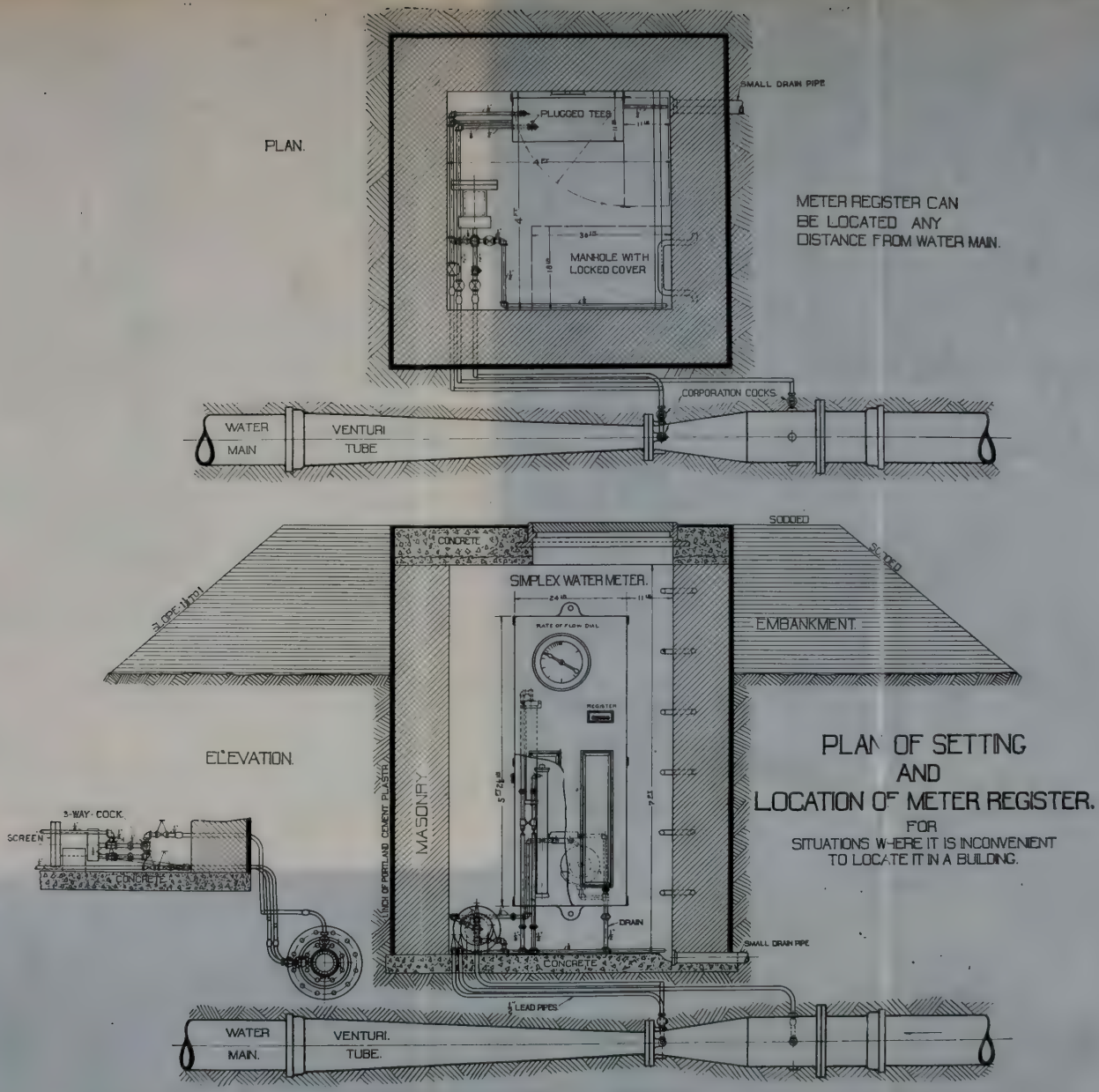
SIMPLEX WATER METER.

J. W. Ledoux.

About three years ago the writer designed an apparatus for measuring the flow of water over dams, weirs or other orifices in which the flow depended on the head of water over the orifice, the purpose being to indicate the total quantity of water discharged by means of a meter dial so that this need be read only at intervals of a day, week or month as desired.

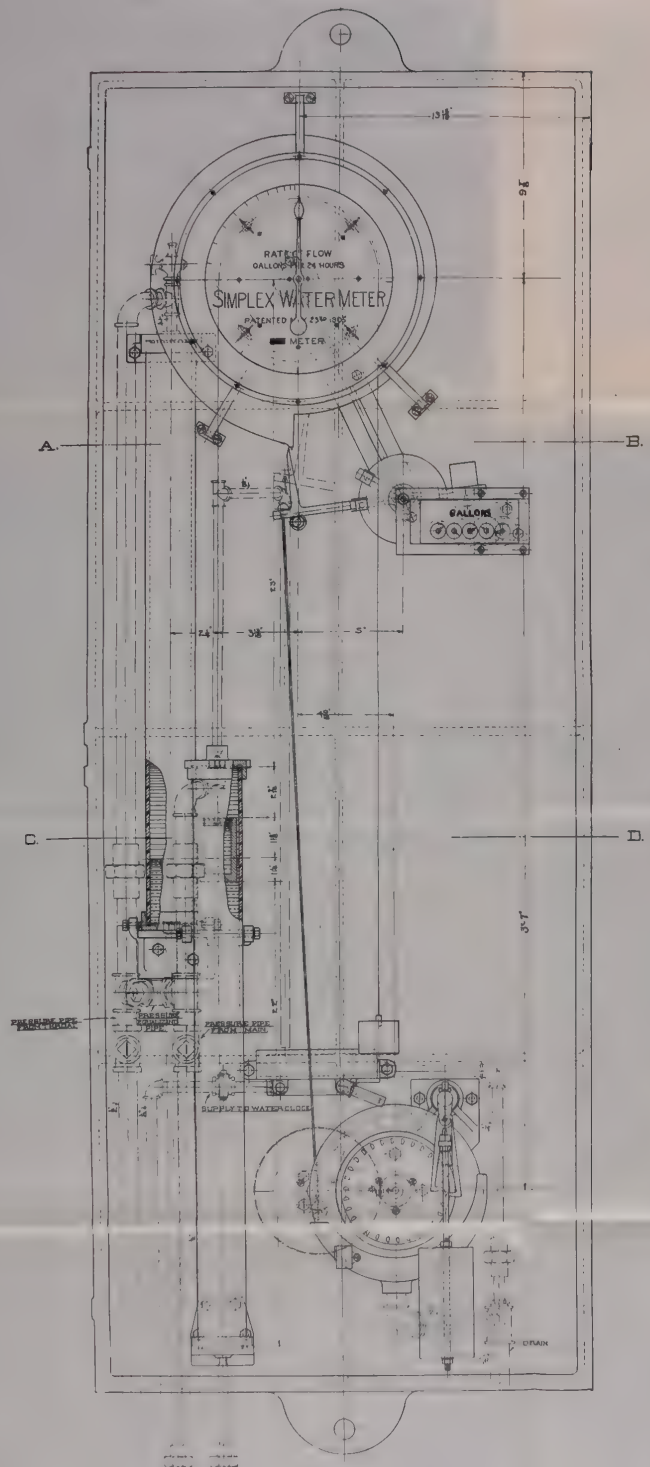
The apparatus consisted of a float located in a vessel, the bottom of which was connected by means of a small pipe running out to the slack water above the dam or weir. The vessel was, of course, placed in a covered vault so as not to be affected by frost. Attached to the float was a wire running over a sheave, and having a counterweight suspended at the opposite end to hold the wire taut. On the same shaft as the sheave was placed a cam, the curve of whose surface was constructed according to the formula of flow derived from a weir or orifice through which the flow was to be measured. In order to make a continuous indication of the discharge, a tappet was designed to come in contact with said cam at intervals of one or two minutes, and a clock work was arranged to move the tappet at constant intervals, the length of the stroke of the tappet, however, depending on the position of the cam. By means of a pawl and ratchet the tappet revolved a wheel on each of the upward strokes, the length of the arc of revolution depending on the stroke of the tappet. To this wheel was then attached a train of gears running the meter dials, the proportions being fixed for measuring the water in gallons, cubic feet or any other convenient unit that might be desired.

In working up the design of this apparatus, its application to the measurement of flow of water through pipes was suggested, and this led through various steps to the design of the present Meter. The first device consisted of a Venturi tube having its largest and smallest section respectively communicating by means of flexible connections with the tops of two mercury tubes, each suspended from the opposite sides of a sheave wheel revolving on the same shaft with a cam. The bottoms of these tubes were

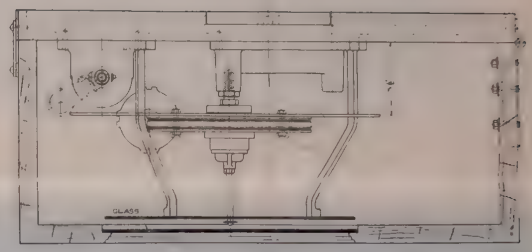


PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906

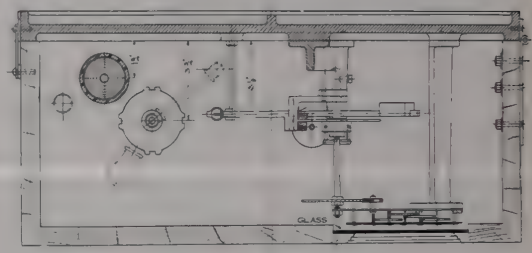
SIMPLEX WATER METER.



MERCURY PIPES



PLAN



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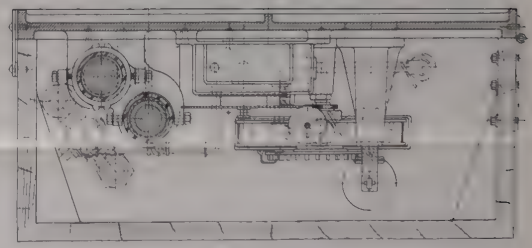

SECTION PLAN C D

connected together by means of a small rubber tube. When the pressure was the same at the top of each tube, the mercury would be at the same level in each, therefore as the flow in the pipe increased, a loss of head, due to velocity, occurred in the nozzle, thus reducing the pressure in the tube connected therewith, and in turn causing a rise of mercury in this tube. The equilibrium being lost, the tube connected with the nozzle, and containing most mercury, would fall and thus raise the second tube until the equilibrium would be restored by means of tension on a spring attached to the second tube, thus also changing the position of the cam according to the relative elevations of the two tubes.

The same form of clock work above described actuated the meter dials in precisely the same way, the stroke of the tappet being regulated by the position of the cam. The real objection to this apparatus was due to the spring, as it is a well known fact that tension springs having the property of considerable extension cannot be easily made of extreme accuracy. The difficulty was overcome in a design in which the counterbalance consisted of a weight suspended in a vessel of mercury, the weight having a section depending on the size of the vessel, the shape of the cam and the total travel of the sheave wheel. wheel.

The second device to overcome the same difficulty consisted of a counterweight suspended from a revolving surface, mathematically designed as to cause the counterweight to have a varying lever arm depending on the difference in weight of mercury in the two tubes. The first of these devices was constructed, tested and found to operate according to previous calculations. Out of this design developed the idea in which a similar sheave wheel and cam was used, but the two tubes are fixed. In one of the mercury tubes there is an iron float resting on the mercury and suspended from a fine nickel wire which passes up through an opening in the top of the tube, which opening is 1-100 inch larger in diameter than the wire, which passes over a sheave and is held taut by a counterweight hanging from the opposite side of the sheave. On the same shaft as the sheave is a cam, whose position is of course determined by the location of the float resting on the mercury. A form of clock oscillates a tappet which in its upper stroke comes in

contact with the cam, the downward stroke being fixed by a stop. The tappet is suspended by a shaft, and at the opposite end of the tappet is a counterweight sufficiently heavy to raise it to contact with the cam when said tappet is not actuated by another force. The middle part of the tappet is forked so as to allow of a disc wheel to revolve within said fork and on the same shaft as the tappet. By means of a clutch composed of balls working in a V groove on each side of the disc wheel, the tappet revolves said disc wheel on its upper stroke, and by means of another fixed clutch of similar design, the disc wheel is kept from running backwards, the action being similar to that of a pawl and ratchet movement. Attached to the disc wheel is a train of gears which runs the meter register. The clock consists of an overshot water wheel run by a jet of water flowing from an open receptacle into which is discharged a stream of water from the main, and in sufficient quantity to keep the receptacle always slightly above the point of overflow. This device maintains a constant head on the jet running the water wheel, and thus the water wheel will run at a constant speed, but to further insure the uniformity in speed a pin escapement is attached to said water wheel, and the movement is made absolutely isochronous by means of a heavy pendulum. The water wheel is then geared to a crank disc which runs a vertical connecting rod which passes through an opening in the tappet and having a ball at its top; thus the connecting rod is free to move upwards without moving the tappet when it comes in contact with the cam, and will only pull the tappet downwards when the ball touches the top of the tappet.

To prevent from clogging up the pipe which leads from the main to the receptacle, the said pipe is provided with a large screen, between which and the receptacle is located a stop valve which is set at the proper opening to maintain the water in the receptacle at the point of overflow. To dispose of the slight amount of leakage passing through the aperture containing the nickel wire, an overflow pipe is also conducted to the receptacle, so that there is really no waste of water. The total amount of water used in this manner and for running the water clock is not more than one quart per minute, which is less than 1-100 of one per cent. of the ordinary rate of flow; and as no meter can be expected to register much closer than one per

cent. it will be seen that the quantity of water used for the water clock is of no consequence.

The cam is based on a formula representing the relation between the difference of level of mercury in the two tubes and the flow of water through the main, so that the meter register indicates directly, without further calculation, the total number of gallons which has passed through the water main up to the time of reading. There is also a dial graduated in gallons, enabling the observer to note by the position of the hand, or needle, the rate of flow in the main at the moment of observation.

The adjustment of the registering apparatus is simple and easy, it only being necessary to close one of the valves and open the by-pass valve between the two tubes. This subjects both mercury columns to the same pressure when the zero of the cam should be in contact with the tappet at the lowest point of the stroke. If these points do not coincide it is only necessary to loosen a screw and slip the nickel wire on the sheave until the points coincide, the wire being clamped in place by the screw.

Heretofore only the most progressive of water works managers, especially in large cities, have realized the importance of metering the water passing through the large mains. A knowledge of the quantity of water used in the various parts of a system of water works is of great value, and where obtained usually results in great saving and economy of operation. Heretofore the maintenance, reading and adjustment of large meters has been considered so great a task that water works managers have hesitated to put them into general use, but where they can be taken care of and read as infrequently and readily as an ordinary house meter this objection disappears.

SIMPLEX WATER METER, CLOSED.

SIMPLEX WATER METER, OPEN.

A NEW HYDRAULIC UNIT.

By Daniel W. Mead.

The great number of units in use in the English and American systems of weights and measures would seem to make it desirable that no other units be added to this already complex system. Yet the very complexity of the system often makes it desirable in special cases to use special units for practical purposes when computations can thereby be greatly shortened. Hydraulic computations relative to flows through pumps and pipes can be greatly facilitated by the use of a unit possessing a circular function, instead of the cubic foot and cubic inch commonly used. The unit suggested for this purpose is the "circular inch one foot long," or what might be termed a "cylinder inch." This may be defined as the volume of a cylinder one inch in diameter and one foot in length. The use of this unit is particularly advantageous in finding the capacity, discharge, velocity of flow through, weight of water in, or weight of water passing through a pump cylinder or pipe where the diameter of the same is expressed in inches. The convenience of this unit rises from the fact that pumps and pipes being cylindrical in section have direct relations to this unit of cylindrical cross section. That is to say, the area of circles are proportional to the squares of their diameters, hence to find the number of circular inches one foot long contained in a pipe or pump cylinder, it is only necessary to square the diameter in inches and multiply by the length in feet, or in the case of the discharge of pumps, by the distance traveled by the piston while producing discharge. The number of circular inches found can then be reduced directly to cubic feet, gallons, weight, etc., by the tabular equivalent, which for some units especially, can be readily kept in mind, and for approximate purposes is susceptible by slight modification of easy mental application. (See note below.)

The following table reduced from "Notes on Hydrology" gives:

THE EQUIVALENT MEASURES AND WEIGHTS OF WATER AT 4° CENTIGRADE—39.2° FAHRENHEIT.

U. S. Gallons.	Pounds.	Cubic. Feet.	Circular Inch 1 Foot Long.
1.	8.34112	.13368	24.5096
.11980	1.	.016603	2.9411
7.48052	62.3961	1.	183.346
.0408	.340008	.005454	1.

NOTE. It may be noted that for mental calculation the number of circular inches in a gallon may be taken at 25 in which case the answer to problems will be two per cent. from the truth, too large or too small according whether the approximate unit is used for multiplication or division. In the same way the weight of a "circular inch one foot long" can be taken at ⅓ of a pound for mental problems, the error being also two per cent.

The following examples illustrate the use of this unit:

Ex. 1. What is the discharge in gallons of a pipe 7 inches in diameter when the velocity of flow is 3 feet per second?

$$\text{Solution: } \frac{(7)^2 \times 3}{24.5} = 6 \text{ gals. per sec.}$$

Ex. 2. Find the contents of a pump cylinder in cubic feet 20″ diameter and 33″ long.

$$\text{Solution: } \frac{(20)^2 \times 33}{12 \times 183.346} = 6 \text{ cu. ft.}$$

Ex. 3. What will be the velocity of flow in a 10″ pipe discharging 700 gallons per minute?

$$\text{Solution: } \frac{700 \times 24.5^2}{60 \times (10)} = 2.86 \text{ ft. per sec.}$$

Ex. 4. If a single acting triplex pump has plungers 8 inches in diameter and a stroke of 10 inches, how much water will it raise at 40 revolutions per minute?

$$\text{Solution: } \frac{3 \times (8'')^2 \times 10 \times 40}{12 \times 24.5} = 261 \text{ gal. per min.}$$

Ex. 5. What is the weight of water in 100 feet of 6-inch pipe?

Solution: $100 \times (6)^2 \times .34 = 1{,}060$ lbs.

MR. WEHR: I will not take the time of the meeting this afternoon to read my paper, which, no doubt, those of you who are interested in this subject have already seen. I desire, however, to say a word which may properly be preliminary to the paper itself.

When we began on the case, which is reviewed in this paper, with the City of Baltimore, something like three years before we actually arrived at the point of arbitration, we searched high and low for some precedent showing the mode of procedure and the methods adopted by other commissioners, arbitrators or courts, in the appraisal of the value of a water works. There are numerous theories that have been, from time to time, advanced, both at the conventions of this Association and elsewhere, as to how properties of this kind should be valued, but there was nothing found in our search which showed that these theories had at any time been either accepted or rejected. It was, therefore, necessary for us, in applying these theories to our case, to show, not that they had been accepted—which was impossible—but to convince the laymen who were to decide our case that they were reasonable—which was difficult in the absence of precedents.

The intention of this paper was merely to put into print, in such form that it could be used hereafter as one precedent, a statement as to how our property had been valued; and I hope that the paper may, in the future, be useful to such of the members of this Association, and to others, as may have occasion to pass through the same proceeding. I trust also that this paper may set the ball rolling toward inducing members of this Association to present papers at future conventions, relating the mode of procedure, the methods of arriving at value appraisals and the actual results obtained, in similar cases, so that, in a few years, when such proceedings will be more numerous, if not daily occurrences, we may have ample precedents for our guidance.

A RETROSPECT OF AN ARBITRATION ON THE VALUE OF A WATER WORKS.

By Albert H. Wehr.

In 1905 there was arbitrated the case of the Mayor and City Council of Baltimore against The Baltimore County Water and Electric Company. Much has been said from time to time on the subject of water works appraisals, but little or nothing could be found wherein it was shown how the various methods and principles of appraisal had been applied, nor has anything come to our notice explaining the method of proceeding in cases of this character, either in the preparation of the evidence, or in the presentation thereof. This paper will attempt to relate in substance what was done in the case referred to, and how.

The facts in this case differ from most others in that only a small part of a complete plant was taken by the City, consisting only of certain water mains, business and territory, while the greater part of the territory and pipe system, together with the entire pumping station, reservoir, standpipe, filters, etc., remained unaffected by the taking. It was for this reason that our case presented dfficulties not encountered in cases where a complete water works plant is being appraised, and we could, therefore, apply only certain methods of appraisal which have been, from time to time suggested, while others had to be invented to meet the exigencies of our particular case. In order to the better understand the matters and facts to be brought out hereafter, it may be well to devote a few moments to some local history and refer to the statutory provision, as a result of, and under which, this proceeding was had.

In 1886 the Catonsville Water Company was formed for the purpose of supplying water to certain parts of Baltimore County. A plant was built, with its proper pumping station, reservoir, standpipe, filters and system of distributing mains, the latter extending rapidly until a considerable area contiguous

to Baltimore City was covered. In 1888 there was annexed to and incorporated within the limits of Baltimore City a certain portion of Baltimore County, in a part of which annexed territory the Catonsville Water Company was operating. For the protection of the Water Company's interests, there was inserted in the statute by virtue of which this territory was annexed, the following provision, which was later bodily re-enacted in the new Baltimore City charter of 1898:

"Before the city shall lay any water pipes along any street, road, lane or avenue in the territory annexed to the city of Baltimore under the provisions of the Act of 1888, upon which the Catonsville Water Company has laid its pipes and other water appliances, the said city shall, * * * pay to the said company the fair value of its water pipes and other water appliances, constructed in said street, lane, road or avenue, and such actual damages to the said company as shall be caused by the acquisition of said pipes and appliances by the city; and the amount so to be paid, if the said company and the said city cannot agree in reference thereto, shall be ascertained by a majority of a board of three arbitrators, one to be appointed by the city, and one by said company, and the two arbitrators thus appointed shall appoint the third arbitrator, and if they cannot agree upon such third arbitrator, the latter shall be appointed by the Governor of the State."

The Catonsville Water Company referred to in this statute was absorbed by The Baltimore County Water and Electric Company in 1900.

The City began to move under the provisions of the above statute in 1902, and after considerable preliminary skirmishing on both sides, and the usually attendant litigation, all of which is not essential to the subject in hand, it was at last agreed to disagree and to arbitrate the matter. The first question was, who to select as arbitrators. Upon the arbitrators rested the entire question, without appeal, and we realized that men should and must be chosen who were "big" enough not to be appalled by amounts running into six figures, men who had dealt with big problems, whose minds were broad and open enough to grasp a proposition, however complex, when it is clearly presented to them, and who possessed sufficient courage to make an award without prejudice, fear or favor, and en-

tirely in accord with their own convictions, after having fairly and fully heard both sides to the controversy. Local sentiment demanded that local men should be chosen, and after carefully looking the field of available men over, it was concluded that the legal profession offered the best material for this special purpose. Following numerous conferences, the City also reached the same conclusion, and the result was that two of Baltimore's leading lawyers were chosen for the respective sides, who in their turn selected the Judge of the United States District Court for the District of Maryland, as referee. You will understand, of course, that during all this time the Company had the preparation of its case well under way, and more than one session was held between the Company's officers and its counsel, in order to impress upon the latter the important facts to be brought out at the trial.

The Statute provided for compensation to the Company for two things:

1. The fair value of the pipes and appliances taken.

2. The actual damage sustained by the Company by reason of the taking of such pipes and appliances.

The first item presented little difficulty, other than the question of depreciation loss on this property, of which I shall speak hereafter, there being included under this head merely the main pipes and valves, the fire plugs having been installed by and being already owned by the City, and the service pipes having been installed at the expense of, and therefore owned by, the consumers. The second item contained, in addition to several minor points of a strictly local character and, therefore, of no interest generally, two elements of value for compensation, as follows:

(a) Damage to the Company sustained by reason of the loss of present net income.

(b) Damage to the Company sustained by reason of the loss of future or prospective net income.

These three elements of value will be treated in the order mentioned.

(1) Fair Value of Water Pipes and Appliances.

This meant the fair present value, or, in other words, the reproduction cost, less depreciation loss, if any. The reproduction cost was a simple matter of computation and was

readily determined. That there was a depreciation loss we readily admitted, but we insisted that at best, this item would be very small on the comparatively small quantity of pipes involved, viz., 5.95 miles of mains, ranging in size from 8 inch down. There was no part of our pipe system more than 20 years old, and some of it had been in the ground less than a year, so that with incomplete records prior to 1900, it was impossible to determine the age of the greater portion of the system.

The City contended that an allowance of 3⅓ per cent. per year should be made for depreciation, based on a life of 33⅓ years for the main pipe, but we met this with the proposition which was very clearly stated by Mr. Daniel W. Mead, in his discussion on the paper read by Mr. John W. Alvord, entitled "The Financial Questions in Water Works Valuations," at the 1902 Convention of the American Water Works Association, and found on pages 154 and 155 of the proceedings of that Convention, from which we took the liberty to quote the following:

"Depreciation is often ascertained by assuming a certain length of life for the particular item. For instance, in the case of iron pipes the length of life is often assumed at 100 years, then if the pipe has been in use twenty years, one per cent. is deducted for each year of use. Supposing that the life is correctly assumed, I believe the true representation of the depreciation is the amount, at the date of the estimate, of an annuity or sinking fund, with accumulated interest, which, if set aside annually, beginning at the time the construction is first completed, will reproduce the value of the pipe at the end of the useful life. Such a fund should of course, be calculated on the basis of a low rate of interest. For example, if we estimate the sinking fund interest at 3½ per cent., the life at 100 years, and the time expired at twenty years, the amount of the sinking fund at the end of twenty years would be $3.27 on $100.00, or about 3¼ per cent. instead of the 20 per cent. as ordinarily estimated."

We had proceeded thus far in our contention, when the City admitted our valuation of the pipe system at reproduction cost, without any deduction for depreciation, but whether the admission at this point, and not earlier, was due to the weight

and soundness of Mr. Mead's reasoning or not, could not be ascertained.

(2) ACTUAL DAMAGE SUSTAINED BY THE COMPANY.

This phase of the question was next taken up, and we proceeded at once to the discussion of the matter of

(a) DAMAGE TO THE COMPANY SUSTAINED BY REASON OF THE LOSS OF PRESENT NET INCOME.

At this point we encountered our first serious difficulty. The question was not as to what should be considered as the net income from the part of our plant to be taken, on the theory that this part is a portion of the whole and hence distributing the operating expenses pro-rata to the gross income, but rather and properly, what is the effect of the proposed taking by the City on the portion of the plant which remains to the Company, or, in other words, what is left after taking a part. We did not, therefore, consider the part of the plant taken, by itself, but we took the net income as it existed before the taking, and from this deducted the net income as it remained after the taking, and the difference was the amount of net income lost to the Company, for which compensation should be made. The following illustration, which states our proposition exactly, has often been used with good effect in cases of condemnations of rights of way through large tracts of land, and may bear repeating here in connection with our case: A. has a coat which cost 100 per cent., from which B. cuts and appropriates to himself a sleeve. This sleeve in itself is worth only 5 per cent., while the value of the coat, by this operation, is reduced to only 10 per cent. of its original value. In compensating A. for the damage done his coat, should he get 5 per cent., the value of the sleeve, or should he get 90 per cent., the difference in the value of the coat before and after the sleeve has been removed. Clearly, he is entitled to the 90 per cent. Apparently B. gets the worse end of the bargain, in having to pay 90 per cent. for something which is actually worth only 5 per cent., but we assume that A. did not invite the taking of his sleeve, and, therefore, he should not be made to suffer through B.'s act. And so it was with the City. Our proposition was considered as rather preposterous when we undertook to say that by our method of reasoning, we charged

against the 26 per cent. of gross income within the City and taken by it, only about one per cent. of our operating expenses, contending that the remaining 74 per cent. of gross income would have to bear the remaining 99 per cent. of operation cost, but then we did not invite the City to take our property. We were bound to see, and the City was bound to see, that we came out "whole," otherwise we would not have been compensated for actual damage sustained. We took great pains to make this proposition clear. Our contention was presented in the following shape, and actual figures are given in order to state the case accurately:

Gross Income, before the taking		$35,803.33
Operating Expenses, before the taking		12,245.05
Net Income, before the taking		$23,558.28
Gross Income, after the taking	$26,434.05	
Operating Expenses, after the taking	12,100.51	
Net Income, after the taking		14,333.54
Loss of Net Income, due to the taking		$ 9,224.74

To ascertain the gross income before and after the taking was a simple matter, and usually is in every instance, and, therefore, need not be dwelt upon here. The reduction in operating expenses, however, presents a more difficult proposition, and will be dwelt upon at some length. In considering this question, we readily determined that the only method of arriving at the reduction, if any, in operating expenses, was by taking up and treating each item of expense separately. Before entering upon this explanation, however, attention must first be brought to the fact that the whole plant involved in this controversy was only one of three separate and distinct plants owned and operated by our Company, near Baltimore, and that our business is not alone the supplying of water, but the furnishing of electric current, as well. All three of these plants are operated from one central office, and though the part of the plant taken by the City was a substantial part of the particular plant involved in this arbitration, it was a very small part of the entire enterprise.

As stated in the early part of this paper, the station, reservoir, standpipe, filters, etc., for operating this plant are entirely in Baltimore County, and were not taken, or in any manner affected by the taking, other than that the quantity of water pumped, filtered and stored was somewhat reduced, because of a reduction in the number of consumers supplied. Our station is operated by water power, although equipped with an auxiliary steam plant, which latter was installed primarily for the electrical end of our business, with provision made, however, for pumping water by steam if occasion requires. We, therefore, did not have the question of reduction in fuel consumption to contend with, and merely showed that the water power cost as much to operate after as before the taking. Our station labor account was not capable of reduction as a result of the taking, because the mere reduction in water pumpage, under our conditions, did not make possible a reduction in our station force. On the question of station supplies, we showed that on our water wheel driven power pumps, we used no new oil, but only such oil as had been used on our dynamos, and then filtered, and in this way we had always obtained sufficient oil of a quality good enough for the pumps, but not for the high speed dynamos, without having to purchase new oil for this purpose. Our waste was first used on our electrical machinery, after which it was clean enough to be used on our pumps. The pump packing we demonstrated to the satisfaction of the arbitrators, lasted practically as long, whether the pumps operated full time or only partial time. And so on, down the line, we treated each item in this manner, showing that in the matter of station supplies there was no saving to be expected as a result of the taking.

Our station repairs account we also excepted from any saving, on the ground that these items are always uncertain, at best, and though there might be a saving, the item itself was so small, the machinery being all new (the station was built only two years before), the reduction in the work of the station so slight, and the saving, therefore, so insignificant, if anything at all, that, whatever the amount, it should be eliminated from the estimate entirely, as a negligable quantity.

Our reservoir, standpipe and filters maintenance accounts we showed would not be in any way affected, since these properties themselves would not be affected by the taking.

Our filters operation account we estimated would be reduced in proportion to the reduction in pumpage, and this saving we placed at 37½ per cent. of the total annual expense, this percentage representing the estimated reduction in water pumpage due to the taking.

Our street mains, valves and fire hydrants maintenance accounts we estimated would be reduced in proportion to the mileage of mains taken and that left to us, namely, 19.2 per cent.

Our service connections maintenance account we treated in the same manner, 46.5 per cent. of the total services being taken.

The meters maintenance account was also treated in this manner, 17.3 per cent. of the total meters installed being taken.

Our buildings and grounds maintenance account, as also our electric pole lines, wires and equipment accounts, were shown not to be affected by the taking, because these properties were left to us intact.

All our general expense accounts, such as general salaries, office expenses, stationery and printing, taxes on County property (Baltimore City and Baltimore County being two entirely separate and distinct municipalities, independent of each other), insurance, stable and miscellaneous, were each treated in detail and shown not to be affected, and therefore, there could be no reduction in these items.

We thus proved that the total saving in operation would amount to only $144.54, or 1.1 per cent. of the whole, and when we were through, the proposition did not seem so very unreasonable; at any rate, the arbitrators did not think it, and we were not trying to convince the City.

Up to this point we had been dealing principally with facts, and though they were such as constituted the very foundation of our case, they were subject to verification from the company's books, its plants and an examination of the methods of operating these plants, and we, therefore, depended upon but one witness to establish these facts, with the assistance of plats of the territory involved, showing the details of this territory, the locations of the Company's pipe system, and the premises of its consumers. Just here, it may not be amiss to specially

emphasize this one point, namely that no matter how important may be the facts it is desired to establish, one witness who is thoroughly grounded in his knowledge of these facts is better than a half dozen witnesses who might fall down in their testimony under cross-examination, and what is equally true is that a witness who has shown in his direct examination his accurate knowledge of the facts, is usually left severely alone by the opposing side.

From this point forward, we were obliged to resort to theories and opinions, most unsatisfactory things at best, and in order to give these as much weight as possible, we retained assistance to provide evidence on the remaining points yet to be covered, namely, the fair and proper rate per cent. at which the loss of net income should be capitalized in order to arrive at the value of this net income, and to place a value on the franchise taken, over and above its present earning capacity, or what we termed in other words, the present value of future or prospective profits. To establish these points, we produced the following witnesses:

The Treasurer of the Company, who could furnish the Company's view on these questions.

Mr. John Kuchler, President of the Baltimore Audit Company, who furnished the accountant's or actuary's views.

Mr. John W. Hill, an Engineer whose ability has given him a national reputation, to give, primarily, the engineer's views.

Mr. Charles A. Allen, of Worcester, Mass., an engineer of recognized ability and an expert water works appraiser, to give, primarily, the appraiser's views.

Mr. Frank S. Hambleton, of Hambleton & Company, leading bankers of Baltimore, to furnish the banker's views.

Mr. Edward Badart, of Owen Daly & Company, prominent stock and bond brokers of Baltimore, to furnish the brokers' views.

It will be noted that we had but one witness of each class or kind, but we obtained the best of each class within our reach.

The rate per cent. at which the loss of net present income should be capitalized, was variously placed by the several witnesses, at from three to four per cent. It was conceded that, whatever compensation the arbitrators would fix, the amount thus received would have to be invested in a sinking fund for

the redemption of outstanding bonds of the Company, and the capitalization should, therefore, be upon a rate at which the principal sum could be safely invested for this purpose. The question as to what would be a safe investment for this purpose, and the rate to be obtained from such an investment, was largely a matter of opinion, hence the difference in views.

We come now to the last element of damage, namely:

(b) DAMAGE TO THE COMPANY SUSTAINED BY REASON OF THE LOSS OF FUTURE OR PROSPECTIVE NET INCOME.

This element of value for which compensation should be made, represents the valuation of our franchise, over and above its present earning capacity; the good will, or the going value, call it what you may.

Our franchise was perpetual, so far as it could be made perpetual under the Constitution of Maryland, and in the territory taken over by the City, it was, because of local conditions, to all intents and purposes, exclusive. In fixing the value of the franchise, we contended that both these considerations were entitled to their just weight. We contended that our plant was a going and a growing concern; that the value of its franchise depended upon its earning power, present and prospective, developed and capable of development; that the valuation put upon it must be its value to the seller and not to the buyer; that future profits must, of necessity, enter into any arrangement which has for its object the sale of a franchise; and that a franchise has no special value, except insomuch as it confers future benefits on its holder.

That future or prospective profits are capable of reasonably accurate ascertainment, we undertook to show in the following manner: We prepared and submitted plats of the territory in question, on which we had sub-divided all vacant land in our territory into lots of the same average size as those already improved or built upon. Next we determined how fast these vacant lots would be improved, assuming as our basis that the development in our territory would continue at the same rate as in the past. By taking the average growth during the entire period in which we had operated in the territory in question, as well as for the past five years, the two results being about equal, as a guide, we concluded that this territory should, under normal conditions, be entirely built up in 68 years. Taking

the average growth for each year of this period and applying to the number of buildings thus shown the average income per tap at present earned, we ascertained the amount of annual income increment, and the total income at the end of the 68th year. By a compound interest calculation, the present worth or value of the income at the end of the 68th year, as well as the present worth of the annual increments during the running of the 68 years, was determined.

Mr. Hill, by a similar method, ascertained that 73 years would be the length of time in which the territory would be fully improved, and based his calculation on this period of time. By a second method, he averaged the net future increments of income and capitalized this average amount as present income; and by a third method, he ascertained from the records of the Baltimore City Water Department the increase in water consumption for a number of years back, and assuming that the growth in population and in water consumption follow each other in a fixed ratio, he calculated that applying this same rate of growth to our territory, it would be fully improved in from 34 to 50 years, and from this made his calculation of present worth. It should be stated here, that we had no means of determining how much of our average daily pumpage of water was consumed in the City territory and how much in the County, because there were no meters placed for this purpose, nor could any have been well placed, without greater expense than the information thus to be obtained, would actually be worth.

Mr. Allen arrived at the future prospective profits by entirely different methods, his first two methods, probably being more easy of application to the average case, than any others suggested. First he took the average income per mile of pipe from several works with which he was personally familiar, and applied this average to the mains still to be laid, and those already laid, in order to cover the undeveloped portion of our territory, and assuming that it would require a period of fifty years to accumulate this total prospective income, he readily reduced the figure thus obtained to present worth, by a compound discount calculation. Second he took the average income earned by our plant per mile of pipe, already laid in our territory, and applied this income to the mains still to be laid

in order to cover the entire field, and by the same calculation, reduced this to present worth. These two methods demonstrated that our plant was within the limits of averages from other plants, and that, therefore, the results obtained with other plants might very properly be expected from our property. His third method was a departure from the preceding two in that here his calculations were based entirely upon the growth of population in our territory. This growth of population for the past 18 years, the limit of time for which this information could be obtained, he represented on a chart by a line, and from this line he projected a curve, from which the prospective increase in population at intervals of five years each, and for 50 years in the future, could readily be calculated. To this increase in population, he applied the present income per inhabitant, and having thus obtained the annual increment in income due to growth of population, he readily reduced this to present worth by his compound discount calculation.

Mr. Kuchler's method was very similar to Mr. Hill's first method, while Messrs. Hambleton and Badart merely "sized up the situation" from a banker's and a broker's standpoint, respectively. and based their valuations on what their past experience, in placing a value on properties of this nature, lead them to believe was reasonable.

It must be apparent from the foregoing, that there was a wide difference between the values placed on the franchise, over and above its present earning capacity, by the several methods mentioned, though the results obtained were relatively interesting, but it was shown that any one of the methods of valuation might be adopted as the correct one and applied with fairness and justice to both sides.

The contentions of the City of Baltimore were briefly these:

That our theory as to the effect of the taking on our operating expenses was erroneous, but as a matter of right and justice, assuming, for the sake of argument, that the effect, contended for by the Comapny, would actually occur, even then the City should not be made to suffer, because of the peculiarities of our plant, and our conditions of operation, to both of which is attributable our inability to cut down expenses, after the taking, in proportion to the reduction in income.

That a capitalization of net income could not be made in order to determine the value of this income, because the amount sought to be capitalized is uncertain, and subject to fluctuation from many causes, and that, therefore, the amount thus obtained should be treated merely as an index to value, and not as the value itself.

That the provisions of the City Charter, under which the proceeding was had, intended to protect our Company merely against present actual damage or loss, and not for any losses, real or imaginary, which might be sustained in the future, and on this point it relied entirely upon the legal aspect of the question.

The sittings of the arbitrators were entirely informal, except that the rules relating to the trial of cases in courts of law were adhered to as to the method and order of proceeding. The City, being the plaintiff or condemning party, opened and closed. Since, however, the City had only such information as was furnished by its expert accountant, who had examined the Company's books, it could not go very deeply into the subject, further than to prove this expert accountant's valuation of the property taken. The City then closed, and undertook to more fully prove its case by cross-examining the Company's witnesses, and after having heard the Company's evidence, to produce additional witnesses for itself, in rebuttal of the Company's testimony. This mode of proceedure was practically agreed upon before the trial began. The arbitrators arranged to sit from 10 o'clock a. m. until 3 o'clock p. m. every week day until the case should be concluded, and the trial lasted about four days.

The award as fixed by the arbitrators was $230,618. This amount equaled a capitalization, at 4 per cent., of our loss of present net income. In their award, the arbitrators gave no reasons or specific details explaining the manner of arriving at their conclusions, but the following inferences can very fairly and properly be drawn from the result:

That the value of the physical property is included in the capitalization of net income, and should not be separately and additionally allowed.

That a 4 per cent. capitalization of net income is a fair compensation for the taking of this income, in view of the

fact that the bonded debt of the Company bears interest at the rate of 5 per cent.

That the provisions of the City Charter under which the proceeding was had, were not sufficiently broad to allow compensation for loss of franchise value over and above its present earning capacity.

A few thoughts occur to me as probably useful to others about to embark upon a proceeding of this nature, which might be mentioned in concluding.

If you have any word in the matter of shaping or drafting the legislation under which a proceeding of this nature is to be had, insist, if possible, upon its being so drawn that it will cover allowance of full compensation for every possible feature of value, and that it is especially clear on the question of compensation for franchise value.

Do not litigate or arbitrate until you have exhausted every means of reaching a satisfactory agreement.

If you must arbitrate, then insist upon having the board of arbitrators composed of the very best material obtainable.

Adhere strictly to facts, wherever possible, leaving the theories for your opponent, and if your contention has any merits, let these merits stand forth prominently and help make your fight for you.

Do not "rest on your oars" until you have "turned up every stone" and seen the under side of it, but do not show the under sides of any stones except those which have something worth showing. To overtry a case is often a greater error than to undertry it. An act of commission is usually deliberate and may be resented, while an act of omission is nearly always pardonable. Avoid both, if possible, and steer the middle course.

Above all, do not try your case in the newspapers, but wait until the arbitrators meet for the purpose of hearing you, and then state your case in such a way as to get them interested in the manner and thoroughness of its preparation and presentation. Through this they will become interested in your Company and its cause. Their sympathy may be helpful.

Discussion

Mr. Kenneth Allen: (by letter). In a recent case in which the valuation of a small water works property was submitted, after years of litigation, to a Board of Arbitration, the following results were agreed upon and accepted:

Cost of duplication	$49,851.10	
Loss incurred in establishing business to date	11,184.90	
	$61,036.00	
Depreciation of plant		$ 2,720.00
Sum required to provide adequate service for estimated income		5,218.00
Net earnings at present time capitalized (a loss)		5,898.00
Resulting valuation of property		47,200.00
		$61,036.00

In formulating the final report the question as to the particular items to be classed under the heads "Physical Value," "Franchise Value" and "Going Value" arose and while all agreed as to the items themselves and the final result, there were different views expressed as to their proper classification.

The views held were:

Physical Value:	
(1) Cost of Duplication—Depreciation.....	$47,131.10
(2) Cost of Duplication—Depreciation—sum required to provide adequate plant...	41,913.10
Going Value:	
(1) Loss incurred in establishing business..	11,184.90
(2) Loss incurred in establishing business—net earnings capitalized.....	5,286.90
(3) Net earnings capitalized (negative)....	5,898.00
Franchise Value:	
(1) Nothing in this case as it was not "exclusive" with reference to the municipality	.00
(2) Net earnings capitalized (negative)....	5,898.00
Miscellaneous items not included in above classification:	
Loss incurred in establishing business—sum required to provide adequate plant (negative)	5,966.90

This indicates the need of a more definite understanding among engineers as to the precise meaning of the terms Physical, Franchise and Going Value. For instance, in a

recent appraisal of the Staten Island Water Works plant by Messrs. Lewis and Hazen, a deduction was made in certain cases on account of inferior quality of water—present and prospective.

Should this reduction be charged to the Physical Value, or, as affecting anticipated profits and not capital cost, to the Franchise or Going Value of the plant, supposing the franchise exclusive?

Inadaptability of a plant may affect its revenue and so its Going Value, but in the absence of competition the income may remain as great as for adequate service. Should the reduction be then made to the value of the physical plant or not?

There is another fundamental point on which there seems to be a variance of opinion: When, if ever, is the valuation of a going concern equal to the capitalized net income only, and when, if ever, should the value of the physical plant be added?

The above points are brought up with the hope that by discussion some common understanding may be arrived at among those engaged in this interesting branch of engineering.

The writer believes that if it were possible to determine the net earnings under good management and fair rates, capitalize this amount by the proper per cent. and then make due allowance for correction of faulty design or adequacy of supply and the existence of any reserve or sinking fund, this would be the ideal method of ascertaining the Physical and Going Values; but he believes that the difficulties in the way of fixing the proper values are often great and that in capitalization errors are increased, so that this method should be employed with caution.

Anticipated profits are dangerous to deal with if it can be avoided, but in the consideration of Franchise Value they must be considered.

In the case of a water company having a limited franchise which was to expire in three years the following method was used: A sum comprising the Going and Franchise Values was added to the Physical Value which sum was determined by discounting the quarterly net earnings for this period, assum-

ing them to remain as during the preceding year. The net earnings being $891 per quarter the cash value was found to be $9,899.84, and this added to the Physical Value gave a total of about $70,000 that was accepted without question by both parties.

MR. ROSAMOND: I would like to make a few remarks on the last part of Mr. Wehr's paper, in which he says, "Above all, don't try your case in the newspapers." We have been going through this procedure for two years, and we have not been trying our case in the newspapers.

We had a good deal of trouble gathering data on this question, but we finally got hold of some three or four cases, one from Massachusetts which was passed on this year, another was passed on by Judge W. C. McMahan in the case of the Valparaiso Water Co. in March 1903.

This question is in the Courts in the case of the City of Omaha against the Omaha Water Co., the City having refused to accept the award of the Commission. We will no doubt get this decision before our next meeting, and we hope to get our matter settled by that time, and will then give you our experience.

MR. MAURY: I would like to ask Mr. Rosamond when the Omaha people printed their report?

MR. ROSAMOND: I do not think it is yet in print, the information came to me by letter.

MR. O. T. SMITH: The U. S. District Court sitting at Minneapolis has rendered an opinion which has not as yet been made public, but will be within thirty days, on the Omaha case. It has not yet been printed.

MR. PRENTER: The company represented by me is up against that proposition now. Our twenty year contract expires next December. The Mayor of the City of Pittsburg recently asked our board of managers to appoint a committee to join with him and councils of the city of Pittsburg in asking the Common Pleas Court of Allegheny County to appoint five appraisers in accordance with our charter and the Act of Assembly to appraise our property. Our company ap-

pointed a committee. One branch of councils complied with his request but the other branch hesitated, and had not complied when I left Pittsburg a week ago. I have some information on the Omaha matter contained in a newspaper clipping which may be of interest to read just now, although I scarcely want it to go into the minutes of the proceedings as newspaper statements are not always reliable, viz.: "Omaha, July 7th—Appraisers in session in Omaha after more than three years' deliberation have fixed the value of the Omaha Water Plant at $6,263,000. This information was received this evening by the City Water Board. The plant is not regarded generally as worth more than $3,000,000, the amount of the bond issue voted for the purchase and which was believed ample to cover the cost of the plant. Under the law, however, the city may be obliged to pay the price set. The engineer representing the city declined to sign the appraisement, deeming it too high. The appraisement was made under the special law authorizing the creation of the water board for the city of Omaha. The appraisement was made to determine the value of the plant, making it obligatory on the city to purchase the plant at the value fixed. It is not known whether two of the appraisers without the concurrence of the third could fix the valuation which the city would be compelled to accept. Since Engineers Benzenburg and Meade have concurred the city may be compelled to go into court to have the appraisement set aside."

I might say that the agreement of the city of Pittsburg with the Monongahela Water Company under which we got an extension of twenty years from December 1886 fixes the method of purchase by the city, the city agreeing to purchase at the end of twenty years and to purchase at the price fixed by five disinterested appraisers to be appointed by the Court of Common Pleas of Allegheny County, Pa.

In this connection would say that when the Ithaca (N. Y.) appraisers recently made a valuation of the private water company there, they determined on a price which was not accepted by the town or City of Ithaca. It is understood that the company has appealed to the Court for an order to compel the City of Ithaca to pay the amount of appraisement. Prof. Williams of Ann Arbor, Mich., who is attending this

convention, was a witness in that case. If he is in the room he might be able to give us some interesting information on the subject.

MR. CHISHAM: I have a letter from Mr. Fairfield, manager of the Omaha Company, saying that he will have copies of that decision printed very soon. If anybody desires to have one they may get it by writing to him for it.

MR. ROSAMOND: I just want to say that I have got the information on my desk relative to this matter gathered within the past years. If it is of any value to have it in the proceedings I will be glad when my notes come to me to extend them to cover that.

MR. CAIRD: I was recently connected with a case in which it was demonstrated that the quality of the water, to a certain extent, controlled the amount of the award.

In his case, I was given to understand by one of the Commissioners, that $50,000 had been deducted because the supply was polluted. The opinion was that $50,000 would have covered the cost of installing an up-to-date filtration plant and that such plant would have made the supply very good.

The Company admitted that the water was polluted and had tried, by injunctions, to have the pollution stopped, but without success.

The City that was buying the plant was one of the foremost polluters of the water supply.

MR. WEHR: Mr. President, there are just one or two points which I desire to touch upon before this discussion is closed. The point has been made as to what part the quality of the water supply of any particular works plays in the valuation of that works. It is true that in some instances this point may properly be considered in valuing the property to be taken, but it appears to me that the propriety of including this subject in the appraisal of value should be largely dependent upon the nature of the creation of the water company in question. For instance, if a water company is given a franchise to supply water from a certain specified source to the community in which the franchise is granted, it seems to me that the quality of the water from such specified source should not be questioned when the community wishes to acquire the works, and

a deduction made because that quality is not all it should be. Again, if the company shows that it is giving the best quality of water obtainable from the only available source—and availability includes quantity, quality and the inability of the company, within its reasonable means, taking into consideration the rates charged for its service, to improve thereon—then the quality of the water should not be taken into consideration in the appraisement; because in order to purify the water, that is to treat and filter it, it may be necessary for the company to increase its rates to meet its increased cost of operation and the cost of installing the additional equipment, and thus the company should be allowed to offset against any deduction which is made because of the quality of the supply, at least an equal amount to compensate for a fair increase in rates which could be made to cover the increased expense. So that, though the quality of the water is a serious and important question, it can only be considered in the light of all the surrounding circumstances and conditions, and when so considered, it is not likely to make a very great difference in the end, because of the possibility of offsetting against any attempted deduction on this score, something else to make up for it.

Mr. Allen, in his discussion, asks that a line be drawn up to which an appraisal based on physical value and beyond which an appraisal based on net income should be made. Is it right to fix such a line, assuming it to be possible, or should not each case stand on its own bottom in this respect and be governed by all the surrounding circumstances? Our case was peculiar in that only a very small portion of our physical plant was taken over by the City of Baltimore. As my paper states, our pumping station, reservoirs and the greater part of our distribution system remained unaffected, only a very small portion of the mains being taken over, and yet this small portion of mains yielded by far the greater proportion of income. Now, in this instance, an appraisal based on the physical value alone would not have been sufficient, because the net income from that part of our plant which was left to us was very materially affected after cutting off the very profitable part at the end of our system. To have paid us

for the physical value alone would have been a great hardship in view of the fact that in our case this was less than ten per cent. of the award, and clearly, an appraisal on a basis of net earnings was the only fair one. It seems to me that this matter might be reduced to some method which, if adhered to, would apply to practically every normal case with fairness. Briefly stated, this method should be something like this: First, ascertain the physical value of the property in question, that is, its reproduction cost less depreciation loss, to this add a valuation of the franchises and any additional elements of value and also deduct any elements of loss which each particular case may contain; second, ascertain the value of present net income, to this add the value of some reasonable future or prospective income to make up for additional franchise values and also add or deduct, as the case may be, any any elements of value or loss which the particular case may contain. If the second valuation is the greater, then such valuation will be the fair appraisal and will carry with it the value of the physical property. If, however, the first value is the greater, then it may or may not be fair to make an appraisal on this basis, for the following reasons, and here I can best state my point by illustrating. My view may be a little optimistic, but I believe that every water works plant which is operating at any place where humanity can live with reasonable comfort, is bound, sooner or later, to develop into a profitable enterprise. Therefore, any works which is not profitable, is so for any one or more of three reasons: (1) it is still in its period of development; (2) its rates are not equitable, or (3) its management is incompetent. The last two defects can ordinarily be corrected and the fact that they exist should probably be considered, but should add to rather than deduct from an appraisal of the value of such works. Such conditions, however, are unusual and need not be considered, so that only the first condition or reason requires attention.

Building a water works, like building a railroad, requires a large initial outlay and brings, at first, a small and usually inadequate immediate return. The period of development is sometimes brief, but usually it extends over a number of years. If a works, which is still in this period of development, is being

appraised, is it fair to capitalize its net earnings only and thus cause the owners a loss? These owners have invested their capital in good faith, upon the assumption, belief and knowledge, if you please, that they will sooner or later get a return from their investment sufficient to compensate for early losses made during the initial period. Certainly it would not be fair under such circumstances to capitalize their inadequate present net income and appraise the works at this figure. In such a case, an appraisal of physical value, plus something for franchise value to cover past losses and to give a share of the prospective profits for the risks of the venture taken by the owners, would be fair under all the circumstances.

So that, as a general proposition, I should say that if you have a losing venture, a fair appraisal would be on the basis of physical value plus a fair franchise value, and if you have a winning venture, then appraise its value by capitalizing the present net income and to this add the present worth of reasonable future or prospective profits yet to accrue. The entire matter, therefore, after all resolves itself into this, as was very well said by the Supreme Court of Rhode Island in the Bristol and Warren Water Works case: "A fair and reasonable price to the town is what would be a fair and reasonable price to anyone else." The question as I view it, is not one of value, because the courts have time and again, in reviewing awards of condemnation juries or commissions upon property of all kinds, said that "the value of anything is the value to the seller who is willing but not compelled to sell, and the value to the buyer, who is willing but not compelled to buy," and in the last analysis, there can be no difference of any consequence between these values; the question is entirely one of how to ascertain it.

The Supreme Court of the State of Maine, in a case in which the Kennebec Water District was interested, had occasion to pass upon the various items which should properly be considered in appraising the value of a water works. As I remember the opinion of the court, there were some twenty or twenty-five items named for which something must be allowed or deducted in making up an appraisal on the particular property involved in this case, from all of which it is evident that the court went very fully into the whole subject.

That case came before the court because of a statute covering the matter, which provided that before the property involved should be appraised, the company and the city interested should apply to the court for instructions to their respective appraisers as to what should be taken into consideration in making an appraisal. The case is interesting as showing the possibilities for complicating what might usually be a very simple proposition, but there is much to be learned from the court's opinion.

In our case there was no appeal from the award of the arbitrators. We would have been obliged to accept an award of $10,000 and the city of Baltimore would have been obliged to pay an award of $1,000,000. Unfortunately for us, the arbitrators agreed with the city's contention on the legal view that we were not entitled to anything further than the actual present and immediate loss sustained by us, and that, therefore, we could not recover for the loss of any prospective or future profits which might reasonably be expected to come to us. This contention was based upon a strict interpretation of the statute under which our proceeding was had. In the absence of this contention, however, the attitude of the arbitrators was such that we are reasonably justified in assuming that, having adopted our view on the question of capitalization of present net income, they would also have accepted our views on the methods of arriving at the value of prospective profits, and very probably have then made an award somewhere near the average valuation as proven by the witnesses for the company, namely $436,000.

Mr. S. A. Taylor: I am interested in this slightly, and am also interested in some plants at which this subject has come up.

In the town of Sebring, Ohio, we were securing a franchise for a plant, and the question of arbitration was taken up at the time the ordinance was granted. We agreed to the following method: That the city and the company would each appoint an appraiser, these two to select a third, and in case either of the parties refused to appoint, the Court of Common Pleas of the County was authorized to appoint an appraiser for the party failing to choose for themselves; and that the result

of these three appraisers would be accepted by both sides, with this one stipulation, that in no case should the result of that appraisement be less than the actual money spent on the property plus 6 per cent. interest after all costs of operation were deducted. This will establish the minimum at which those appraisers could make a return. Anything beyond that, of course, would be obliged to be accepted by both parties, but it would give a minimum at which the water company would be treated in a measure fairly guaranteeing them against any monetary loss.

Mr. Reimer: The paper presented has been of deep interest to me. In looking over the past results of our own city, East Orange, N. J., the system presented seems good and fair, but as showing a rather unscientific method versus the scientific method presented by the writer, the experience at East Orange is perhaps an example. There the preliminary exercises were gone through of high prices, etc., offered by the company and rejected by the city. A commission was appointd by the court, their award was made and rejected by the city, and then the newspapers got in their work; and that is why I speak of it as absolutely unscientific. The writer here has said, "Don't try your case in the newspapers." Now, that is a splendid axiom for the water works corporation, but for the municipality I think the other law could be used, if East Orange is any criterion, for the newspapers got pretty busy about the time when the award of the commission was rejected by the city council; and it was only a few months after that when the water company came down and gave a price practically one-half of what the commission had awarded, accepting the valuation placed by the city in their first deliberations, a practical acknowledgment that the commissioners had made a mistake and that the original figures of the company were simply to create an impression; and finally East Orange got the plant for what it was really worth to the city. The city bought practically all of the plant. That case differs from the case presented by the writer of this paper; but I think we cannot fix a law that applies both to private companies and to municipalities. I think that for private companies that is a splendid rule, "Do not try your case in the newspapers." Perhaps the other rule should be

adopted by the municipalities. The newspapers can sometimes help in that case.

Mr. Wehr: I wish to say just a word about trying your case in the newspapers. As I stated when presenting my paper, our case went along for something like three years before we actually got down to arbitration. During that time numerous attempts were made by the newspapers to interview the officials of our company. We declined always to speak. We were on the defensive, and did not care to publish any defense we might have until we were properly called upon to make one, and then we proposed making it as effectively as possible. We never, however, hesitated to discuss the matter freely with the city officials, but we let the city do all the newspaper talking, which it did without harm to us. The city began at the very beginning of this controversy with the newspaper statement that our property was worth $15,000, and from that figure on their statements gradually rose higher and higher, until the offer made us by the city for our property, just before going into arbitration, was $195,000. The ideas of the value of our property in the public mind increased as the city's figures increased, and we did not care to spoil this good work by publishing our figures, so that when the arbitrators awarded us $230,000, the newspapers called it a victory for the city, and the public was pleased. Had the award been a half million, the effect would probably have been the same, and so long as we got the money, we were perfectly willing to leave the laurels to the city. Had we spoken, the public would have considered as unreasonable any figures we might name, and to have created such a sentiment might have injured our cause. So that, in view of the usual antagonism of the public against all public service enterprises, it is unquestionably wise not to talk until you are before the proper tribunal, but if you can, encourage the other fellow to talk, in the right direction of course, as much as he will so that you may get his thoughts and you will be better prepared to meet him at the proper time. It was this I intended to convey when I advised against trying your case in the newspapers.

SOME INTERESTING FACTS REGARDING THE GREAT EARTHQUAKE OF APRIL 18, 1906, WHICH WAS FOLLOWED BY A GENERAL CONFLAGRATION, INVOLVING OVER HALF OF THE ENTIRE CITY OF SAN FRANCISCO, CALIFORNIA.

By L. J. Le Conte.

The writer thought that the physical data connected with this great calamity and its all important bearing upon the water-supply of the City of San Francisco would furnish a most interesting subject for discussion. The writer does not pretend to know *all about the facts,* because they have not come to light as yet, but only such as have been well ascertained up to the present time.

As a result of the quake a great fissure was developed, extending, as far as known, from Point Arena on the North nearly to Point San Luis on the South—covering a distance of some 300 miles. This fissure can be clearly traced all the way throughout this course. At the northerly end of the fissure there is evidence to show that the *slip* was fully fifteen feet. At the Spring Valley Reservoir, near San Mateo the *slip* was fully 8.0 to 8.5 feet, and progressively less as we advance southerly. The fissure strikes the Coast-line at Point Arena, thence up Gualala River and thence along the axis of Tomales Bay to Bolinas, thence across the entrance to the Golden Gate to Mussel Rock, thence along the Chain of Lakes made by the Spring Valley Waterworks, San Andreas, Crystal Springs, Searsville Lake, Portola, etc., down to Chittenden and Pajaro Valley to the Salinas River, and up the Salinas River as far as the vicinity of Paso Robles, beyond this point it has not been traced with certainty, but probably goes into the Ocean near Pt. San Luis.

This quake lasted for twenty-eight seconds by seismograph record. It was the severest shock experienced by Californians since the earliest record, and the mechanical effects are quite remarakble.

One of the most vital effects was the entire cutting off of the city water supply, by which the Fire Department was robbed of all its usefulness, when the general conflagration set in, shortly after the quake. Fires broke out at fifty different places all over the city and rapidly spread so as to baffle all the fruitless efforts of the dynamiters who were wrecking buildings, trying to check the progress of the fire.

The *three supply mains* leading to the city were completely wrecked, thus cutting off all new supply. The large distributing mains within the city limits were torn asunder and the local service reservoirs, in spite of all efforts, emptied themselves in twelve hours after the quake, leaving the city without a drop of water to fight the fire with. The large emergency reservoir, *Lake Merced,* situated in the city limits, was put into service as soon as possible, but too late to be of any service, and a limited supply of water was furnished to the unburnt district.

It seems to be quite clear now that the present distributing system of pipes in the city will have to be materially changed in order to meet the quake requirements as near as possible.

In looking over the wreckage and ruins one is much struck by the marked difference in the physical effects of the quake on the *high solid ground* and on the *low and made land.* On the latter the destructive effects were very severe. The lesson to be learned from the quake is that the larg distributing mains within the city limits must be laid on the *solid high ground,* where the shock is much less pronounced, and that the *smaller distributing mains* should then lead down into the low lying and made ground. This rule should also apply to the supply mains leading to the city, which can just as well be kept up on the high solid ground, where they will be largely out of danger. Furthermore, the city should use all the high hill tops for emergency reservoir sites, which could be made ornamental and ought not to detract in the least from the beauty of the Parks. In case of another break in the supply mains these local reservoirs would come in very handy when most needed.

In the made land district, near 18th and Howard streets, the large distributing mains, as a precaution, were made of wrought iron with bell joints of cast-iron, at short intervals. After the quake all of this pipe was in good condition except where the

ground displacement was greatest, at which point the pipe was torn asunder.

This quake has clearly demonstrated the great value of wrought iron pipe to stand the convulsive strains brought about by the earthquake shocks.

The Pilarcitos supply-main, wrought iron riveted pipe, unfortunately lies right on the *line of the fissure,* and of course, is badly wrecked for 3,000 feet—pulled apart forty inches in places, and telescoped in other places—showing great local distortion of the ground. The fences in this neighborhood seem to show a *slip* of 7 to 8.5 feet. There seems to be some grave doubts about the advisability of ever rebuilding this pipe line. The location of the pipe line will have to be entirely changed to some other site, involving the probable expense of some $400,000 to $500,000, and it is highly probable for this reason that some other line may be used instead. Owing to the terrible financial straits into which the Spring Valley Water Company has now been suddenly precipitated, some such policy will have to be adopted. In addition to the enormous expense to which the water company has been subjected by reason of the earthquake damages and fire losses, they will also suffer a still greater loss of at least *fifty per cent.* or more in *monthly income,* which is now entirely wiped out by the destruction of the city. In its hour of trouble they should justly be entitled to their share of public sympathy.

PROTECTION OF METER REGISTER.

By C. E. Loetzer, Supt. Sayre Water Co.

Water meters are purchased and installed by *water companies* primarily for a twofold purpose: First, to correctly determine the revenue on a fair and equitable basis for the commodity (water) furnished. Second, to protect themselves against theft. And unless the mechanical appointment of the meter is such as to successfully furnish this dual service, it fails of its purpose, and proves inherently defective and a snare and a delusion, equal to the degree of its inability in rendering that service.

It is not only important that the meter shall correctly register the amount of water passing through same, but is of much more importance that the amount so registered be protected against improper manipulations.

Water meters to be reliable and of full benefit to water companies *ought* to embody two essential features in their mechanical construction, viz.:

First, accuracy of register.

Second, protection of register against improper manipulation.

The first feature is fairly well furnished in all present standard meters, *the second feature is entirely lacking in same,* in that they are so constructed that any experienced person can in a very few moments easily remove the register cover and mechanism, set the register back to lesser count (steal water), and replace same without detection. To provide against this inherent defect in meters, water companies are obliged to resort to various schemes and makeshifts, such as placing car seals, wax seals, tin covers and other contrivances on the meters with a view of securing this protection, in which they utterly fail, as they do not only *not* protect, but prove objectionable and unnecessarily expensive as well.

Seals Do Not Protect.

A seal on a meter is not a parallel to a seal on a car. Before a seal is placed on a car an accurate record of its contents is made and preserved, which can be checked against in case seal

is broken, thus revealing the theft, if any there may be, and the amount of goods stolen.

A seal on a meter simply seals the record (register count) so that when a meter seal is broken and the register count is set back the record itself becomes destroyed and lost and there is then no way of determining the theft or the amount of water stolen.

Seals Prove Objectionable.

To the dishonest consumer the presence of the seal merely serves to arouse his curiosity to investigate its meaning, thus causing him to discover how very easy it is to tamper with the register, which he is very apt to take advantage of, hence causing the seal to serve a contrary purpose from that intended by the water company. To the honest consumer the seal proves offensive in that he feels his honesty is questioned by the water company, resulting in strained relations between the consumer and the company .

Seals Are An Unjust Expense to Water Companies.

Inasmuch as all present make of meters fail in their construction to protect the register count against manipulation, and water companies are obliged to purchase seals and resort to the various methods and schemes now in vogue in their endeavor to protect same, all at considerable cost, such expense is unjustly, though unintentionally imposed upon them by meter makers, for the reason that this protection ought to be embodied in the mechanical construction of the meter, making further expense to water companies unnecessary.

The Legal Status Concerning Meter Seals.

The breaking or removal of the meter seal does not in itself furnish the evidence sufficient to prove theft or the amount of water stolen; it merely serves as notice to the water company that they have a case of "watch" on their hands. The broken seal may, and usually is, accounted for by the guilty party with various plausible excuses, such as that the children may have removed it, or plumbers or other workmen in making repairs to pipe and premises may have done so, etc., etc. In all such cases the burden of proof rests with the water company, as the evidence of theft must be positive to secure conviction. This means expensive and bitter litigation, which the

construction of the meter can and must make unnecessary. Protection against stealing register count must not be contingent upon the use of seals and fear of the law and courts, as the case now is, but must be an inherent feature of the meter to which water companies are justly entitled with its purchase and use, and it is incumbent upon meter-makers to furnish an instrument that shall satisfactorily perform the functions for which water companies are paying and which they have a just right to expect to receive.

I trust that the time is not far distant when water companies will be relieved of the necessity of paying exorbitant legal expenses and attorney fees, and the further necessity and expense of purchasing and placing seals and contrivances with a view of securing the desired protection, but that same will be furnished through the intervention of the meter as an incorporated feature of its construction, to which end the hearty co-operation of all waterworks owners and superintendents interested in securing honest revenue for honest service rendered, is earnestly solicited.

Mr. Loetzer: It is quite one thing to point out a defect, or criticise, and quite another to point out the remedy. I have had made at my expense and upon my special request by two different meter companies some modifications of their meters. I will say here in justice to all meter companies that I believe that all of them would have extended the same courtesy, but I did not have the time to take the matter up with more than two. I was very much in doubt whether I would be able to attend the Convention. I am very glad that I came; there are many new things that I have learned and seen here which I value. I have here meters showing the modifications for your inspection, if you wish to see them. I am not in the meter business, and I hope I never will be; I have trouble enough of my own in running a water plant. One of my troubles is to secure honest revenue for honest service rendered, and this has caused me to give the matter the serious attention and study that I did in order to learn how to meet the difficulties I encountered. The modifications which I have incorporated in the present make of meters will thoroughly eliminate the difficulties that we are now laboring under to which meters are susceptible.

If it is satisfactory I will explain the idea. It may facilitate matters. You are all familiar with the present style of meter. We have in our town some 600 meters set, with a prospect of having 2,000 within the next five years. We place all our meters in the cellar, finding it much more convenient. I am not singling out any one make of meter, gentlemen, my talk is general. We place it just as we get it from the factory. There are two screws there. The man who places the meter takes those screws off, replaces that and puts two screws back on again. Now we place a seal on the meter. You understand that we have not sent men around to place seals on all of the 600 meters in service now, because it might awaken inquiry and would lead dishonest consumers to discover something that we don't want them to know; on the other hand, the honest consumer might take offense. So we have considered that and also the vast amount of labor it would mean to us to change the meters, etc. So we have not found it practical to make one business of it and seal all those meters. The

Water Company furnishes the meter, giving a minimum rate plus a slight charge for the use of the meter. If we find that the seal that we have placed there has been broken or destroyed and we charge that consumer with the breaking of the seal and the stealing of the water, we have made a serious accusation which we will probably not be able to prove; but assuming that we absolutely know that he has done that, and can prove it to him, then we have no fear of his getting back at us and making it unpleasant and disagreeable. As seals are ordinarily used, if one is found to have been tampered with, the consumer will say that he does not know anything about it and that if it has been taken off or destroyed it must have been by accident, etc. That is the situation as it stood before we made this little modification. In making a study of the matter it occurred to me that that could be overcome so that when a dishonest consumer did steal water or tamper with a meter he would leave ocular evidence so strong and so indisputable that we could take it into court and secure a conviction.

Mr. Prenter: Could that not be taken out accidentally?

Mr. Loetzer: No, sir. The ordinary excuses will not prevail in that case. Now in this other meter there is a slightly different situation. Here you find the same left-handed thread, with the exception that this is drilled off. Let us assume that the screw has been introduced in that thread, it is then covered with putty and painted, and presents an unbroken appearance. The dishonest customer even if he knows how that is done is obliged to mutilate that to find that point (indicating). After he has found that he must remove that screw and he is then obliged to hook on to that left-handed thread. The probabilities are that he will try to twist it in that direction, resulting in mutilation or breaking and leaving evidence so strong that, as I said before, it can be taken into court for conviction. But if he does not know how it is made, which we assume will be the probability when meters are placed, he will try all manner of means to get at the mechanism. If he attempts to pry that up or to unscrew it he is bound to leave the evidence, and he will be so baffled in his efforts to steal water that I will venture to say 999 times out of 1,000 he will conclude to leave it alone, and the object for which I am contending will be accomplished. I again thank you, gentlemen.

MR. F. L. FULLER: I would like to ask the gentleman how often he reads those meters.

MR. LOETZER: Every three months. In further explanation I wish to say that assuming you read them once a month, it would naturally be either at the beginning or end of the month, and there is ample time between the two readings for a dishonest consumer to get in his work. We had one case where a man had a specially made device to tamper with the meter. He would remove the meter and leave it on the floor, replacing it just before he thought we were coming around to examine it. We caught him at it by coming at a time when he did not look for us.

MR. CARLIN: In our city we have about 3,100 meters. We read a certain number of them every month, about 1,300; and all of our meters every six months. I do not know what remedy we could have in a case of that kind. I was going to ask the gentleman that question. Another thing, I find oftentimes in looking over our meters that they are reversed in the settings. What would you do in a case of that kind?

MR. LOETZER: Just prior to setting I place this under the meter. This covers the register. The meter on turning around I claim is susceptible to similar modifications, thus making it very difficult for a dishonest consumer, in placing so many obstacles in his way as to prevent him from doing it. I have no axe to grind in the matter. If there was a blackboard here I should be glad to make an illustration for the benefit of the Convention showing how it can be done; also for the benefit of the meter people.

MR. CARLIN: What would you do in my case? We have a pumping capacity of about four million gallons to supply a population of 45,000. Last year our per capita was about 35 galls. We handled about 4,800 taps, 3,100 of which are metered. We pumped less than a million and a half galls. per day for the year 1905. I do not know why we should give them all that free water. I am afraid that those who want to pay a good price, or a minimum price for water, would be without water in our district.

MR. LOETZER: In our town we do not ask people to put in meters. To one man having all modern improvements in his

premises, hot and cold water, lavatory, closet and all that sort of thing, we charge a certain flat rate, which under the conditions of filtering and pumping every drop of water was exceedingly modest, we think—$4.25 per quarter of three months, giving him all the water that he wants unrestricted. He came to our house and said he wanted a meter put in. It is optional with our customers to demand a meter. We put the meter in his house, and the next quarter we found that man was down to the minimum—$2.30.

Mr. F. L. Fuller: I would like to say in connection with this meter question that in the town where I live we have everything metered. It is a small town and we have perhaps 1,000 meters. We read our meters once a month. Perhaps it is an exceptional town, but I never remember to have heard of any trouble due to tampering with the meters. I think it will be interesting if some of the gentlemen here who use a great many meters will tell us whether they have cases where meters are tampered with, set back, or the dials changed.

Vice President Felix: That is very pertinent; and if there is any information here as to the extent of water stealing where meters are in use we should be glad to hear it.

Mr. Worrell: I found, in a few instances, where meters had been taken out and reversed; in other cases, where we kept close watch, we found that they would either remove the dials althogether or smash them when they knew a considerable quantity of water had been used.

Vice President Felix: Would not this idea help all that?

Mr. Worrell: I think it would, like other meter seals, have a beneficial effect but it is susceptible to the same abuse; for instance, should the seal—either this or those already on the market—be broken there is no evidence against the meter burglar who broke it unless, perchance, a friend happens to observe it.

Mr. Loetzer: The gentleman did not get my idea. When that hole over the screw is covered with lead and the letter S is over that—and all meters that we are setting are in that condition—if the consumer takes that out and destroys it we have evidence to go into court and say, "That meter was set in such a manner having this letter on it. This is the meter

as it came out of the man's house, and the letter S is not there now."

VICE PRESIDENT FELIX: You would have to have evidence that that particular meter was set in that way.

MR. WORRELL: Another thing, you would have to prove who did it, and you would have some trouble in doing that, as much so as in the case of a seal.

MR. VOLKHARDT: I have also had a little experience and found that about the best thing to do is to read your meters every month, and what discrepancies you find settle the best way you can, which costs less than going into court. I think at our next Convention we will have a paper, probably along this line, as to what is the best plan to pursue, to read them monthly, quarterly, or at longer periods. While I always saw that my meters were read monthly, I did not render bills monthly; but it was to overcome things like this, or anything else that might crop up.

MR. F. L. FULLER: I would suggest as a strong reason for reading meters monthly, that when a meter stops there is not so long a time for which it is necessary to adjust the probable consumption of water.

Also, if there is a leak, causing excessive leakage of water, it is shown by the meter readings, and is more likely to be sooner repaired. From my own experience I am convinced that meters should be read at least once a month.

FIRE PROTECTION.

What is the Proper Basis for Charges?

By Joseph Torrence Miller.

A brief experience in the water works business has brought the writer to believe that water companies do not receive an adequate compensation for the services that they render in furnishing fire protection; that this is the result of an improper idea as to what should be the basis of a charge for fire protection; that it is also particularly caused by the parties interested, i. e., the public and the water company, not fully realizing what the furnishing of fire protection would actually cost the company; that but few realize that to construct a combined service for the furnishing of fire protection and also for the delivery of water for domestic and manufacturing purposes, costs twice as much as it does to furnish either of the single services. In the State of Pennsylvania it is an established principle of law that if a plant will earn it, a company is entitled to at least the legal rate of interest (6 per cent.), and is also entitled to make a system of charges for the services they render, that will give sufficient revenue to maintain the plant, to pay the fixed charges and operating expense, to provide a suitable sinking fund for the payment of debts and in addition a fair profit to the owners of the property.

It seems to the writer that an erroneous notion has crept into the minds of water works people, to the effect that it is necessary to lay large mains for manufacturing and domestic purposes at a heavy initial cost, and that it costs no more than the mere price of the hydrant to furnish fire protection, and that everything received from fire protection is simply pure "velvet." The most prominent engineers that it has been my good fortune to meet have assured me that a combined plant, i. e., one that is intended to furnish water for domestic and manufacturing purposes and also for fire protection services, costs about double what a plant would cost that would be built to furnish only water for manufacturing and

domestic uses. The amount of money that is put into a system should bring a fair return and the amount of money that is invested in fire protection should, therefore, pay its equal half of the revenue of the Company, or very near that. Fire protection is nothing more or less than insurance, and insurance in a "wild-cat" company is not of much account when you are very uncertain as to whether you will be able, in case of fire, to collect the amount of loss or not; but when your insurance is placed in a company of great financial strength, the chances are good in such case that you will get all your policy allows you, if your buildings are destroyed. Poor fire protection is not cheap at any price. The protection should be ample to an extreme and the company furnishing it should be paid an adequate compensation for what it furnishes.

It seems that early in water works history and the furnishing by said works of fire protection, that the rate of so much per hydrant crept into consideration and instead of having placed an ample protection in all cases, the temptation was ever present to hold down the expense of the Borougns or Municipalities contracting for such protection to the lowest possible notch; that instead of setting the number of plugs that should have been placed, one-half or one-fourth of this number were set, simply in order to save money and to furnish a semblance of fire protection, securing thereby any possible benefit from the same that our insurance company friends are willing to allow. Under these conditions towns that to the writer's knowledge should be covered by at least fifty plugs, have but fifteen or twenty. This is surely false economy. I heard of one case recently where a fire occurred in a remote part of a town, and to reach the same it was necessary to lay 1800 feet of hose. You can easily imagine what sort of a fire stream would be secured at a nozzle on such a string of hose even with 110 lbs. pressure at the plug. The result was, that the building was lost, together with three adjoining structures, and only vacant lots prevented the wiping out of that part of the town. I have also heard that sometimes politics enter into the awarding of fire protection contracts, but of course this would only possibly occur and in extreme cases.

I, therefore, believe that the only basis that should be used

in getting what should be paid for fire protection is to consider on the one hand the value of the property protected and on the other hand what it has cost to furnish an adequate protection, using the principle of law recognized in Pennsylvania; that the return to the company from the amount of money invested by it for fire protection should be enough to yield the legal rate of interest on the actual money put in the plant to furnish said fire protection; to pay at least one-half of the maintenance charges of the plant, and also of the fixed charges of the company; to give the company at least one-fourth, or more properly, at least one-third of its operating expense and to furnish at least one-half of the amount set aside by said company for suitable sinking funds, which are to be eventually used for the payment of any debts and for the renewing of the plant, i. e., depreciation account.

It is fully realized that what would be reasonable and fair charges in one case would probably be exhorbitant in another case. There should be no such thing as private fire protection, in my mind, for large manufacturing plants, as the plant means the life of its town and the town itself should furnish, without expense, full and complete fire protection, but that plant should pay its full and complete share of the taxes that are assessed for the benefit of the town. By paying its taxes it would be paying its share of the cost of the fire protection to the whole community. In my opinion, factories without towns, in most cases, are not much better than towns without factories. I do not believe in metering fire protection. When furnishing fire protection, a water company is not selling the water, but is selling insurance against loss by fire and is selling something that cannot be gauged by meters. The protection is a sort of intangible, indefinite thing that cannot be measured by so many hundred cubic feet of water. Think what it would mean in the saving of wealth in this country, if by means of ample and complete fire protection, the fire loss in one year were reduced to a minimum amount. I believe that each dwelling should be equipped with inside protection and should pay its pro rata of the expense of furnishing that protection. Private fire protection and the payment therefor is simply an effort on the part of the individual or the corpora-

tion, to make up a deficit of the protection that should be furnished by a municipality, in the same manner that some individuals and corporations find it necessary to furnish private police and watchmen in order to protect themselves more fully against thieves and criminals generally. The principle is wrong in both cases, to my mind, as the public should furnish ample protection to both the liberties, the persons and the properties of the citizens of this great republic.

Water departments are looked upon as being owned by the people, which is right, and are to a singular degree supported accordingly. On the other hand, water companies are "bloated" corporations in most people's eyes, intended only to squeeze out the last possible penny from the poor and defenseless citizen; a grinding and soulless oppressor of mankind, to be opposed and fought at all points as the opportunity offers, who are to be denied what they ask no matter whether it is in reason or not, but simply as a matter of principle.

I believe that no fire protection appliances should be supplied under meters, but that fire lines of all descriptions should have thereon devices to prevent theft and that all outlets should be sealed; that in case any seal is broken, the consumer should be required to notify the water company at once, who would investigate the cause thereof and if the same is legitimate there would be no charge on account of it. If the seal had been broken unlawfully, or in violation of the agreement, that the consumer be made to pay for the said violation.

The company that I represent has been working somewhat along these lines and with a certain degree of success, which I believe will become more pronounced as the public which we serve becomes better accustomed to the idea of demanding full and ample protection, paying for what they get on the basis of the value protected, and getting away from the old notion of buying fire protection at so much per plug.

In closing I wish to state, that the ideas given above are only suggestions, the value of which I have become firmly convinced.

BOILER PLANT ECONOMY.

C. H. HURD, URBANA, ILL.

1. It is probable that the item of the cost of fuel and general boiler room expense is the one which is more variable than any other for the different plants of the country. While this is atributed largely to the difference in location in respect to the coal supply and transportation facilities, there is no doubt but what it is due to a more or less extent to the amount of attention which has been given in each case to the boiler room equipment and the economy of operation. This quantity is not only extremely variable but almost universally the largest of the operating expenses, and as the cost of fuel does not seem likely to decrease to any considerable extent, it is a matter of importance that the methods and means employed in the production of steam should receive consideration.

2. During the last few years there has been a universal development in our water works systems. This rapid growth has been the natural outcome of our increasing and centralizing population and progress made by our manufacturing industries. This has meant a more adequate supply, usually larger mains, more substantial pumps and additional boilers. And, while it has been necessary for the water works engineer to be alert to present demands and to anticipate future requirements, it is somewhat questionable in many cases, if he has not given his best efforts to the points which have required his immediate attention, the result being that too often the boiler plant has been neglected and is far inferior in equipment and efficiency to the other parts of the system.

3. Until within recent years the general conception of a boiler plant has been an equipment which would furnish an ample supply of steam at the required pressure to be reliable in times of emergency, and to require as little care as possible in operation. The idea of a boiler room foreman has been a "practical" man and one who could meet the above requirements. It has been the prevalent notion that whenever these conditions have been met, and providing there has been no considerable amount of waste of coal in the ash, that all that could be expected in the way of economy had been accomplished.

4. It is not at all unusual to find the estimate of the efficiency of a plant to be based upon some previous test rather than upon actual daily performance, and while such figures may not agree with the totals at the end of the year, the difference is somewhat explained by poorer coal, more exacting service or some more difficult condition. The writer has been frequently impressed at times when such trials are proposed, that the boilers are seldom ready, and almost without exception it is necessary that they should be cleaned, repairs made upon the settings and everything put in as nearly perfect condition as possible. Not only do the boilers receive special treatment, but there is almost always an additional effort on the part of employees to give more attention to fires and methods of firing which makes it practically impossible to have such a test which is representative of the average practice, and the results are not only misleading as to the efficiency of daily performance, but they do not give proper data for judging the merits of the various furnaces and stokers which may be used. What the water works engineer and manager should be interested in is not what the plant can do under some favorable circumstance, but what it does and can do under every day working conditions; and it is the purpose of this paper to consider the plant under such circumstances, together with a discussion of a few of the principles which tend to give a higher economy in operation.

5. It is conceded in advance that there are many good as well as poor plants. And it is of some little satisfaction to those who are interested in the problem that the apparent lack of interest in this particular is being appreciated, and that many plants are, or are being, equipped with more modern appliances. Yet it matters not how elaborate this equipment may be if there is not skill and judgment used in the operation the efficiency may be but little better than that of the more antiquated plants.

6. Perhaps there is nothing which will help to promote the general economy of a power or pumping plant like a system of daily records. The average engineer usually finds himself too busy to go into the intricate details which are connected with all the departments of a system: yet by means of such reports he is able at all times, not only to have positive knowl-

edge of the operating costs, but to have in definite form the effect of changes or improvements upon the plant. Besides such records being almost indispensible to the engineer, the fact that they are being kept and the information at hand is always an incentive to employees to do better and more careful work and to study and to attempt to reproduce the conditions which produce the best results, and such investigations almost invariably lead to a more specific knowledge of the methods of combustion in the boiler room which is one of the most vital factors in the economy of a plant.

General Considerations.

7. It is evident that the average performance of boilers is always below what can be done under favorable conditions, and while there may be times where it may not be practical to keep the plant at the highest point of efficiency, it is desirable that the average shall be as nearly as possible to the maximum. If sufficient data was at hand, there is no doubt but what it would show that the efficiency of the average plant is at least from twenty to twenty-five per cent. below what it is possible to accomplish, providing it was well adapted to conditions of fuel and load, and properly operated.

8. The adaptability to coal and load is one of the most important things to take into account in the *construction* of a plant. While in general there may be but little difference in the efficiency of the various types of boilers, in each individual case there should be a careful selection to meet the requirements imposed, not only in regard to the size but the character of setting, and particularly the type of furnace or stoker to be used. In this respect it is essential to give special attention to the fluctuations of load, and whether such fluctuations are sudden and can or cannot be anticipated. In the choice of a furnace or stoker it is necessary to give attention to the quality and kind of coal which is most likely to be used, and the selection of a boiler may be governed largely by the character of the furnace or stoker.

9. While the function of a boiler is to absorb and transfer heat to the water or steam, and the furnace to produce as much heat as possible from a given quantity of coal in the best form to be transferred, the efficiency of one may be almost entirely dependent upon the other. A good boiler can not produce good

results unless the gases are highly heated, as the completeness of transfer depends upon the difference in temperature; on the other hand, it is not possible to get the best results from a furnace or stoker unless the boiler is adapted to a setting which will give an efficient combustion. To accomplish this it is necessary, that there shall be no cooling surfaces in direct contact with the gases before the combustion process is completed, that there shall be no air currents entering in such a way as to lower the furnace temperature, and that there shall be such an intermixing of the air with the fuel in a zone of sufficient temperature that the amount in excess to what is required for combustion shall be a minimum.

The Choice of Fuels.

10. The fuel problem, which should be taken into account in the building or remodeling of a plant, is also one which requires considerable thought in plants already constructed, as it is frequently necessary, on account of changing conditions, to choose between various kinds and grades of coal which is upon the market. In making such a choice the principal thing to be considered is the cost per unit of steam, and to make a selection which will fit both the equipment and the requirements. While a certain grade of coal might work well under a given set of conditions, it would not be practical at all under different conditions either with stokers or hand firing.

11. The character, or governing features, of the various coals are determined by the amount of moisture and ash, the tendency to clinker, and the amount of volatile matter present, also whether they are quick or slow burning, and will or will not stand storage without disintegration. The volatile matter, or hydro-carbons, and clinker are perhaps the most troublesome in the operation of furnaces. The former on account of the tendency to produce smoke and the necessity of having a furnace or stoker of such a design as to make the escape of combustibles impossible, while the clinker makes many furnaces or stokers impractical which would otherwise serve the purpose.

12. At times when contracts for coal are to be let, providing there are not sufficient boiler room records at hand, the best practice is no doubt to run a short series of tests, using one boiler or the entire plant as the circumstances will warrant.

The object of such tests is to make a direct comparison of the coals used, duplicating as nearly as possible the average practice of the plant. Supplementary to such trials the use of a good form of a coal calorimeter is almost indispensible, and a very good means of identifying the coal during the year. This instrument with some kind of a gas analizer for measuring the quantity of gas, and a thermometer for determining the temperature of the flue is practically the entire equipment necessary for such trials. Great care should be taken in the use of the calorimeter, as well as the gas analizer, to obtain an average sample, as considerable error may enter into the work if special attention is not given to this particular.

13. While such tests are of little value, as before stated, in judging the actual economy of a plant, almost invariably they give valuable information as to boiler room practice, and particularly the relation of the quality of coal to the capacity and efficiency. The evaporating capacity of a boiler depends primarily upon the amount of heat which may be generated in the furnace, and if we have both capacity and efficiency this must be at a high temperature. Coal which is high in moisture and oxygen not only will be low in heat value, but it will also give a lower furnace temperature. The coal of some districts may run fairly uniform in quality, while that of others may vary from good to medium and from poor to worthless. It is not a good way to buy coal upon the reputation of the district, but rather upon a guarantee of quality as determined by analysis, which should include moisture, volatile matter, ash and sulphur. The contract should also define and specify the grade as to size, and if "run of mine" the percentage of fine allowable. With such a specification in definite form there is less chance for misunderstanding, and the probabilities are in favor of a more uniform and reliable quality at the plant.

Boiler Room Methods.

14. It is well understood that the efficiency of a boiler, and that of the furnace are entirely distinct. The furnace which will give the highest efficiency is the one which will deliver to the boiler the greatest number of heat units per pound of coal, at the highest temperature. The boiler which will give the highest efficiency is the one which will absorb the greatest number of heat units for a given condition. The combined

efficiency, or what is usally termed the "boiler efficiency," when the heat is taken in terms of the pounds of combustible, varies according to the different conditions, particularly as to the rate of driving and furnace temperature. A high rate of driving tends to decrease the boiler efficiency, but since the amount of air remains fairly constant, there will be a higher temperature in the furnace, and in the average case the combined efficiency will be increased.

15. While the effect of a higher rate of driving and that of a higher furnace temperature are directly opposed to each other, by taking into account that the heat transfer is proportional to the square of the difference of temperature, it is easily seen that it is possible to design a plant with a proper relation between the heating surface and the furnace or stoker capacity so that the working of one will not seriously interfere with the other, and that it will be practical to get the best performance out of the furnace without overworking the boiler. It should be the duty of the boiler room foreman to see that these conditions are met, and by increasing or decreasing the number of units in service attempt to keep the plant at the maximum point.

16. The "overworking" of boilers is a term which is very often misunderstood. While it should mean a point where the heating surface is insufficient, as indicated by a perceptible decrease in the ratio of the furnace to the final temperature, the latter being reasonably low, it more often has reference only to the final temperature. For instance, if we should have a boiler working under constant conditions with a furnace temperature of 3,000 degrees F., and a final temperature of 600 degrees F., it is evident that there would be a 20 per cent. loss of heat in the gases; at the same time if we should have a boiler with a furnace temperature of 2,000 degrees, and a final temperature of 600 degrees, there would be a 30 per cent. loss. But, if we were burning the same quantity of coal under each boiler, it is probable that the amount of air in the second case will be approximately 50 per cent. greater than in the first, which will tend to give a higher flue gas temperature depending upon the rate of driving. Assuming this to be from 800 to 900 degrees, the loss of heat in the gases alone would be represented by from 40 to 45 per cent. Thus, it is seen

that the economical capacity of a unit depends directly upon the efficiency, and this largely upon the regulation of air into the furnace.

17. The amount of air which is admitted to a furnace depends upon the difference in air pressure above and below the grate and the total area of the interstices between the coal particles. This will, of course, vary according to the fineness of the coal and the thickness of the fire; so while the draft may remain fairly constant, depending upon the temperature of the gases, the quantity of air will be almost in direct proportion to the condition on the grate. Experience shows that better results may be had with a thick rather than too thin a fire, the thickness being governed by the tendency to cake, the degree of fineness, and whether or not it is subject to clinker. In case there is any considerable amount of clinker present, difficulty may be experienced in keping the conditions uniform, both with hand firing and some types of stokers. Yet, this should not be true providing the stokers are of the proper design.

18. It is scarcely possible to give any careful thought to the problem of boiler and furnace economy without being convinced of the advantage of mechanical and automatic stokers. The fact of having a continuous and uniform supply of both coal and air with a possibility of having these in the proper ratio for combustion, is one of the best arguments in their favor. With a hand-fired furnace, besides their being expensive to operate on account of the labor required, there is always a chance for the fires to be in poor condition when there are heavy demands for steam. This is particularly true with western coals. Even if the fires do not need cleaning at such times, the opening of the doors, and the cooling effect of moist coal is often sufficient to defeat the purpose, for some little time at least, of the additional coaling. There is no doubt that a properly designed stoker, properly installed, and properly operated, will help to solve many of the difficulties which are connected with the burning of bituminous coals.

19. The principles of combustion and operation are not different for stokers than for hand-fired furnaces, but the advantage of the stoker is almost entirely due to the ability to keep the conditions constant. The hand-fired furnace may

show at times fully as high economy as the stoker, but the economy curve will vary over a wide range, depending upon the amount of attention and skill of the operator. It is notable that most stokers make but little better showing when under test than can be had from hand-firing, yet this in no way holds true in every-day practice. The stoker not only eliminated to a large extent the personal factor of the operator, but by reducing the number of men in the boiler room, makes more intelligent supervision possible. As has been mentioned, one of the most important features in connection with the use of stokers is to make a proper selection for the conditions imposed. In a general way, the best stoker will be found to be the one which is the most automatic and requires the least attention, the one which will maintain high temperatures, and be least variable to conditions of fuel and load.

20. The best boiler room practice in all cases will be found to be the result of thoughtful and careful effort to produce conditions as nearly as possible to the ideal. The best operator will be the man who is able to judge his fire, not only the relative temperature, but to anticipate and forestall difficulties which might prevent his realizing maximum efficiency. Some of the principles which will tend to increase the economy of a plant and which will be noted by a careful observer, will be found to be:

1. Burn as much coal as possible with the least draft possible.

2. Keep a fairly thick but loose fire upon the grate.

3. The furnace should be worked up to such a point where it is necessary to hold it back rather than to force it.

4. Attempt to keep the fire and heat as much as possible in the front end of the boiler.

5. Do not let holes occur for the admission of cold air either through the fire or the setting.

6. By keeping the heating surfaces free from soot, incrustation and sediment, the flue gas temperature will be reduced and the boiler will be found to be the most effective.

NOTES ON COMPARATIVE EFFICIENCY OF CAST-IRON AND RIVETED PIPE.

By L. J. LeConte.

Experience at and near San Francisco, California, has been particularly valuable in developing the relative value of these two classes of pipe. In the earlier days, say in 1867 and 1868, it was very hard to get cast-iron pipe at any price and as a result necessity compelled the old pioneer engineers to make riveted pipe. Later on these pipes were coated inside with Rosendale cement lining, which in places added much to the life of the pipe. As the City of San Francisco increased in population the unavoidable loss of water, due to leakage in the distributing system, soon became unbearable. Steps were at once taken to replace the city pipes with cast-iron as fast as possible. This very soon brought the consumption per capita down to the present rate, about 70 gallons per head per day for a population of 500,000, which agrees pretty well with eastern experience.

Across the bay at Oakland, California, population now 100,000, there seems to have been a lack of foresight in this direction, and although cast-iron pipe is being slowly introduced in the distributing system in place of the old pioneer riveted pipes, yet the fact remains that they still have some 76 miles of the old riveted pipes in service, and as a result we have the enormous per capita consumption of 180 gallons per day, which can best be explained by inordinate leakage in the distributing system.

The natural life of riveted-pipe well coated and carefully laid in average soil may be safely placed at 40 years. This refers to good wrought-iron riveted pipe, of which we have good record. Experience with steel pipe is more limited.

The natural life of cast-iron pipe, well coated and carefully laid in average soil may be safely placed at 75 or 80 years.

Experience everywhere seems to show conclusively that riveted pipe is par excellence the best and cheapest for all ordinary pipe lines and for supply mains leading from the intake to the city limits. After entering the city boundaries the only

pipe which will always give general satisfaction is cast-iron. The principal reason for this being not so much the increased life of the pipe as the far better facilities they naturally offer for making good tight taps, which will not leak. This is the weak point with all riveted pipe, cement lined and Converse pipe. The metal is too thin and you cannot make a good efficient tap and, moreover, the leakage from these taps grows worse and worse with increased pressure and age. The introduction of meters of course can not affect this loss.

A new element has come into the field of late years, namely, electrolysis, which is growing to be quite serious. The manifestations so far are chiefly at and near the power stations where the return current leaves the pipes. We are slowly gaining experience in this direction, but up to the present time cast-iron pipe seems to stand the new enemy much better than the other class of pipes.

Steel vs. Wrought-Iron for Riveted Pipe.

Much controversy has arisen of late years in regard to which of these is the better for riveted pipe. All of the older and more experienced engineers cling to wrought-iron as the best pipe, and base their opinion on old existing pipelines, which, of course, is hard to refute. On the other hand, the steel-men, who are rapidly gaining control of the entire market, maintain that it has not yet been proved by a single case on fair trial, which may also be true. There seems to be little doubt about the fact, however, that the average steel used for pipe is a heterogenous mixture of high-grade, medium, and low-grade, all milled up together in one sheet.

It is maintained, with some force, that this inequality in the character of the metal must surely bring about internal galvanic action, which will very materially increase the annual rate or degree of rusting. This, of course, shortens the life of the pipe somewhat. Future experience alone will settle this question. As steel is now practically monopolizing the market to the complete exclusion of wrought iron, this open question may never come up again. That is to say the cheapness of steel pipe will undoubtedly drive wrought-iron pipe out of the market, in spite of its slight superiority. Should the steel men be more careful about maintaining one grade of steel in manufacturing plates then this superiority would vanish.

HIGH PRESSURE WATER SYSTEMS.

F. L. Hand, Late Chief, Bureau of Water, Philadelphia.

The question of having an adequate water supply for conflagration purposes was fully impressed on the city of Philadelphia by the action of the Board of Underwriters in the year 1900. The insurance companies at that time increased the rates on all risks, and twenty-five cents per one hundred dollars insured was the extra tariff added to all properties located in the congested district, bounded by Delaware Avenue and Broad Street on the east and west and by Race Street and Walnut Street on the north and south. Covering an area 1½ miles east and west by ½ mile north and south, or an area of 480 acres. Distributed through this area are the large wholesale houses along the Delaware River front, and all the large wholesale and retail stores and office buildings one is apt to find in the congested business district of a city numbering one and one-half millions of inhabitants. The increasing of the rates of insurance twenty-five cents per hundred dollars naturally raised a stormy protest from the business men, and the matter was immediately taken in hand by the Trade League. A committee of whom waited on the underwriters to obtain information concerning their action in increasing rates. The underwriters replied inadequate water supply and fire-fighting inefficiency. Both bodies recognizing this awaited on the Mayor of the city, with a proposition that if a more efficient fire service could be had the underwriters would bring their insurance back to the old rating. The Mayor of the city, feeling the hardship of such an increased rate made upon the business community, immediately instructed me as Chief of the Bureau of Water, to devise a method of water supply for conflagration purposes that would be effective in not only reducing insurance rates but increasing the efficiency of the fire department, so as to enable them to cope with large conflagrations for all times to come, that is to say, be adequate enough to keep pace with increased size and area of new structures.

To meet this proposition I immediately recognized the futility of getting adequate water supply through my distribution system as well as any portion of the said system standing the high pressure required to meet this proposition. It seems to

be an axiom throughout the land that water pipes and sewers never grow with the population. I have argued for years before City Councils that the erection of large hotels, office buildings, manufacturing establishments, department stores, and the like, demanded a revision of the water distribution throughout our congested district, but I could not convince Councils of the importance of an appropriation.

I do not wish to imply in my statement concerning the distribution system that it was the cause of any increased rate, for they were fighting fires for years off of it, but I do mean that where a district develops from three-story to twenty-story structures, pipes that were formerly adequate for steam fire engine service and supply were proving inadequate under the new developments.

In considering a new and efficient fire fighting medium I was deeply impressed with the importance of an independent pipe line service, isolated from service connections and planned to withstand a water pressure of 300 pounds per square inch. I do not believe any distribution main, no matter of what size it may be, can be trusted to deliver an assured supply of water even under moderate pressure, owing to the existing multitude of service connections which are apt to break in one or more places, and thus hamper the supply.

A number of heavy fire losses attributed to wind, etc., could often be directly traced to lack of water supply through the breaking of large service connections.

Again, the increase of fire department efficiency by purchasing more engines for a certain district is a misnomer unless the water supply is correspondingly increased. Many cases occur at fires (requiring three alarms to be pulled) which brings to the fire grounds some twenty-five engines, with the resultant effect that less than one-half of them if in fair working condition, will drain the average distribution main in a district nearly dry, therefore, water and fire department efficiency should, for correct working, advance together.

In considering this proposition the main problems to be solved were as follows: First, an independent pipe service entirely free from any connection with the existing distribution system. Second, the use of raw water for conflagration purposes. Third, a power plant independent of any other pumping

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HIGH PRESSURE WATER SYSTEM.

plant in the water department, and such a power plant being called on intermittently for service required for economical operation that the usual stand by losses be eliminated. Hence the motive power—steam, gas or electricity, had to be considered along economical and assured lines. Fourth, the standard of efficiency in fire department equipment and management had to be correspondingly increased to meet the new conditions of a 300-pound working pressure, which was to be maintained without diminution as long as required. Fifth, the combined high pressure system to be equivalent to twenty of the best steam fire engines in the Philadelphia fire department, the same to be rated with a pumping capacity equal to five hundred (500) gallons per minute. Returning to the subject of steam vs. gas or electric power, I made a report based on Philadelphia practice. The figures cover estimated operating cost.

Items.	Steam Plant.	Gas Plant.
Number of engines	3	8
Capacity million gals. per 24 hrs.	15	16
Number of boilers	8	none
Cost engines, boilers and stack	$140,000	.....
Cost engine	.....	$150,000
Wages per month	$650	$450
Cost of coal at $2.00 per ton	500	.....
Cost of gas at $1.00 per M	.....	$392
Cost of fuel per hour	$50	39.20
Oil and waste	48	48
Repairs	85	85
Total cost per month	$1,283	$975
Total cost per year	$15,396	$11,700
Saving in per cent. of steam plant		24 per cent.
Saving basis equal capacity		29 per cent.

The above figures cover estimated operating cost per month exclusive of fixed charges and upon the basis of one fire per month of ten hours' duration.

The cost of running per year will show a much greater difference in favor of the gas engine than is shown in the table, from the fact that gas is used only when required, which

might be considerably less than ten hours' per month.

The first cost of a gas engine and pump is greater than that of a steam engine and pump, but the additional boilers and stack for the latter makes the total first cost of both plants about equal. Including fixed charges in the total operating expense, the saving becomes still greater. Upon the basis of the following figures the fixed costs are as follows:

	Steam.	Gas.
Capacity, gallons per 24 hours..	15,000,000	21,000,000
Building	$50,000	$50,000
Sub. foundations	7,500	7,500
Machinery and foundations	175,000	200,000
Total	$232,500	$257,500
Cost of steam plant on pro rata basis of equal capacity.....	$326.000	

	Steam.	Gas.
Cost equipment per million galls. capacity	$15,500	$12,250
Interest on investment, at 5 per cent.	16,300	12,875
Depreciation average 7½ per cent.	24,450	19,300
Insurance and taxes	none	none
Total	$40,750	$32,175

Saving ..... $8,575, or 21 per cent.

SUMMARY OF SAVING, GAS OVER STEAM.

Initial total cost of equipment.....	21 per cent.
Estimated operating cost	29 per cent.
Estimated fixed charges	21 per cent.
Total operating cost	50 per cent.

Although estimated percentages are subject to much modification by variable, local conditions, these figures given are directly applicable to the Philadelphia plant under the assumptions named; as an example, treacherous sub-soil was encoun-

tered which added 15 per cent. to the cost of building construction. The general saving due to the use of gas power shows, then, not only in net operating cost, comprising fuel, labor and repairs, but also in cost of equipment and fixed charges, which form as legitimate a factor in total operating expense as the cost of fuel itself. In building cost alone 35 per cent. is saved by the general compactness of the machinery, and the dispensing with a boiler house. Considering in addition the immense improvement in simplicity of operation by doing away with boilers, heaters, pumps, condensers, and piping under pressure, as well as absence of standing losses. The whole subject of fire protection by high pressure pumping stations is so new, and the conditions so different to any other service, that in making comparisons between various systems the ordinary arguments for and against have little application, and must be regarded from an entirely new viewpoint. For example: In the ordinary power plant, whether used for pumping, lighting, car service or manufacturing, low cost of operation during use is the most important consideration, since this is the normal condition of the plant. In fire service this really is of small account, since the normal (and ideal) condition of the plant is standing idle, but ready for use at any moment.

The reverse is equally true, the cost of maintenance while standing idle is of small account to the ordinary plant, but is the chief item in a fire service station.

Similarly, while certainty of starting and of operation are *desirable* in the ordinary plant, they are absolute necessities in fire service, and a pumping station which is liable to be ten minutes late in starting or to stop for half an hour while running, might as well, in fact, better, not be built at all, since dependence upon it would lead to the neglect of other precautions.

Wear due to operation is of great moment in the ordinary plant, while in the fire station it is of little importance, owing to the low total running hours, but non-liability to accident is a large factor with the fire service, since its infrequent operation gives none of that opportunity to detect gradual deterioration or misadjustment which constant running gives in the ordinary plant. Comparisons based on the first cost,

too, require absolutely new treatment, owing to the entirely different conditions governing depreciation and replacement. Considering the subject in this way we may set the various requirements of a high pressure pumping station in the following order of importance.

Certainty of starting promptly on call.

Certainty of operation when started.

Low first cost of maintenance when standing idle.

Low liability to depreciation or accident when standing.

Low first cost.

Low cost of operation when running.

Three systems are open to any place in considering high pressure pumping plants:

First, steam pumps and boilers. Second, electrical driven pumps taking current from a central station. Third, gas engine driven pumps.

The usual condition in which a steam plant is considered to be ready for instant service is either with fires laid in quick steaming boilers or with fires banked and some pressure on in ordinary boilers; to be truly ready, the boilers must have steam up, fires burning freely, and engines or pumps hot and turning over slowly. This entails prohibitive expense. It may be argued that this may be done where a city has a steam pumping plant for its ordinary service, but this I shall discuss under the head of electric drive.

Steam machinery may be considered reliable in operation dependent on the usual limitations of stuffing boxes, piston rings and steam pipe lines with their joints, drip valves, etc. Steam machinery costs almost as much to maintain when standing idle as when operating regularly. It must be run constantly or the rings and internal parts will rust, and perhaps stick fast, and a few days' rust scraped off will equal many weeks' honest wear, besides the fact that all the damage is done internally where it is difficult of access for examination.

A pump driven by electricity from a central station is a very tempting proposition, especially as local companies will often make very low offers for power for such a purpose. In the case of sewage disposal, or the like, where the power will be used wholly or chiefly during the hours of light station load, such an offer is a legitimate business proposition.

The idea that by closing a switch the power is instantly available is most enticing, but it must be remembered that *electricity* is *not* a generator of power, but only a means of transmission, exactly as a belt or rope is, and the limit of power which a central station can furnish on sudden call is the actual *surplus* boiler, engine and dynamo capacity in *use* at the moment of alarm.

In other words, to be fully fitted for an electric driven station the electric company would have to install, in addition to its regular plant, boilers, engines and dynamos to 25 per cent. greater capacity than your pumping plant, and keep this apparatus under constant steam ready for use. No company will do this except for an enormous rental or maintenance charge, and, if they would, it would be simpler and cheaper for one to install a steam plant and save the cost of the electrical conversion of energy.

For reliability of operation of electric pumps I can only refer to the liability of interruption of service. The *safety* devices required for the protection of the central station machinery are the *danger* devices which may cut off your supply at any minute or instant, and the fire which you are fighting may disable the overhead lines which supply your power. Even in Philadelphia, with its many stations, and all underground electric mains, in the two years of operation of the high pressure pumping station the one failure of any part has been the interruption for half an hour of the ignition current from the Edison mains. As we equipped the station with three different methods of ignition this caused no trouble, but it is suggestive that the only failure of any part should be the outside electric current.

Every failure of lights, every stoppage of the trolley cars, means that this might happen to a fire plant, and if these happen on an apparatus which is a part of the regular and daily operation of the station, what would it be when you throw on them without warning from 200 to 1,000 H. P.? If there is any class of machinery subject to depreciation in an unseen and undetected way it is motors and dynamos. So thoroughly did we recognize this in the Philadelphia plant that in using electric ignition we installed no fewer than three independent methods and congratulate ourselves that the only one which

has ever failed, failed outside the pumping station.

Compare with this the gas engine driven pumps as installed by us in Philadelphia. In over two years of actual service, including alarms of fire, several of the most exacting tests by the city officials and experts from the underwriters, and constant runs for training and practice of attendants, not once has any one single unit failed to get full pressure on the mains in less than one minute, actual timing.

The average time is 40 to 45 seconds, the record time 27 seconds from the time the alarm sounded, with a further record of 9 engines started and pumping 10,000 gallons per minute in less than 7 minutes; the whole being done by the regular crew of one engineer and two oilers.

No unit has ever stopped during a run, and before the plant was accepted one unit was taken at random and run over-load for twenty-four hours without a moment's stop and when shut down the oil cups were simply shut off and the engine reported ready for duty. The only thing which can effect the Philadelphia station would seem to be a failure of the gas supply. I am not prepared to answer for other localities, but in this city there is no recorded failure of gas supply in forty (40) years.

The gas engine and pump cost nothing when not running, the instant you do not need them the closing of the gas valve cuts off fuel expense. No banked fires, no wasted coal or oil, no steam pipes to watch, only the wages of the men to pay, and the slight charges for waste, etc., to keep the plant clean. I cannot offer a better argument than the Philadelphia plant. It has converted the underwriters from opponents of the gas engine proposition into its warmest advocates. And Philadelphia has the honor of being the first in the world to establish an independent central power station for use as a fire fighting medium only.

The high pressure fire pumping station was put into service under the jurisdiction of the Department of Public Safety, February 15th, 1904, on which date the fire boats were discontinued as a source of water supply to the special pipe lines

As the mechanical installation called for a guarantee of one year after completion by the contractors, steps were immediately taken to carefully try out all the mechanism under various

High Pressure Fire Service, Philadelphia, Pa.—Test of Fire Streams.

loads and conditions, these tests applying to every engine and pump. These tests, coupled with actual service since erection have more than demonstrated the value of a central power station as a fire fighting medium, and exceeded the expectations of every one connected with this new fire service.

The completion of the fire main pipe lines resulted in a reduction of insurance rates amounting to fifteen cents per hundred dollars, with an additional proviso on the part of the Philadelphia underwriters that a further reduction of ten cents per hundred dollars would be made upon the entire completion of the pumping station, making in all a total reduction of twenty-five cents per hundred dollars, whilst the pumping station and completed pipe lines were turned over to the Department of Public Safety for active service on February 15th, 1904, it was not until April 19th, 1904, that the full reduction in insurance rates (mentioned above) was allowed by the underwriters.

The cause of the delay was the fact the underwriters were adverse to the reliability of the gas engine as a means of motive power, and they demanded a test before their experts before accepting the plant. With this idea in view, they furnished me with a routine of operations which they desired the plant to fulfill, and are as follows:

PHILADELPHIA FIRE UNDERWRITERS' TEST:

First. The station shall be started and run with the smallest number of men who ever would be on duty at a given time, and the reliefs shall be allowed to come on duty as they would in actual service.

Second. The minimum time of operating all the engines shall be twelve hours (not necessarily consecutive hours) for all engines, slight breaks being allowed for observation of results, but such twelve hours shall be the sum of the run times of the mean number of engines under operation. All times when the engines are at rest due to the shutting off of nozzles, shall not be considered running time. In fixing this time we desire to note that a serious conflagration might demand continuous use of the station for 24 or 48 hours, and that a 12-hour run does not seem to us more than might be called for under conditions which are liable to prevail at any time.

Third. The water discharge shall be from two separate stations on Delaware Avenue, the location of such stations to be determined by the city authorities, and the tests shall be made through orifices of a known size and construction, so that the actual discharge can be computed from tables already in our possession, this discharge to be maintained at a minimum pressure of 250 pounds per square inch at the pumps.

Fourth. The engines shall be started in such a way as to demonstrate whether or not the capacity of the air storage is sufficient to start all the engines under the most adverse condition, and as the test of starting under actual service conditions, one engine shall be started up under load so that it is discharging water at a maximum pressure within two minutes, the second shall be started in six minutes, the third in twelve minutes, and each additional engine in ten minutes.

Fifth. From the time at which the preceding engine was started, all engines to be kept in operation until all are started and as long thereafter within the 12 hours as may be thought advisable by our committee.

(Signed) HERBERT WILMERDING,
Secretary, Board Fire Underwriters.

The plant fulfilled the most exacting conditions, and this even under the operation of a staff whose experience at that time with the mechanical equipment had not reached the standard of efficiency existing at the present day.

The entire plant was operated from 6 a. m. to 3.30 p. m., with one unit running continuously 12 hours, 6 a. m. to 6 p. m. The entire pipe service, nearly nine miles, was subjected to the maximum pressure of 300 pounds per square inch for a period of four hours without a defect showing.

The entire installation has more than fulfilled the conditions projected by the city authorities and contractors, the plant representing the largest installation of gas engines and the only central power station of its character in the world, is deserving of a full description, which is attached hereto.

The engine room at the pumping station is 68 feet wide by 140 feet deep, and contains 7 large gas engines, each 300 break horse power, and 2 small gas engines, each 125 break horse power, making a total horse power of 2,350. To each of the large engines there is attached a pump direct connected

HIGH PRESSURE FIRE SERVICE, PHILADELPHIA, PA.—TEST AT RACE ST. WHARF.

HIGH PRESSURE FIRE SERVICE, PHILADELPHIA, PA. TEST OF FIRE MAINS.

and delivering 1,200 gallons of water per minute, and to each of the small engines there is attached a pump delivering 350 gallons of water per minute.

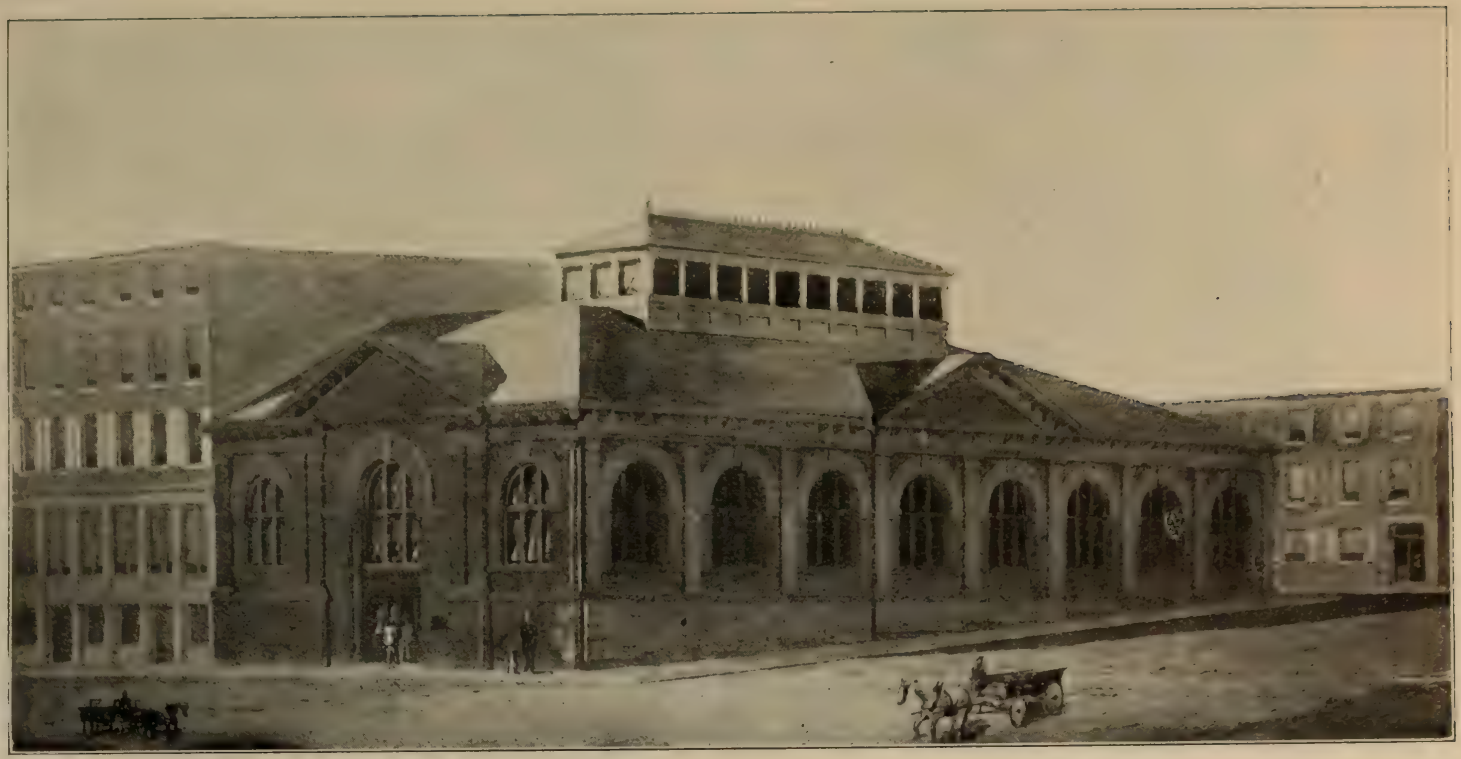
Each gas engine is of the vertical, three-cylinder, four-cycle type, made by the Westinghouse Machine Co., of Pittsburg, and erected by the M. R. Muckle, Jr., & Co., contractors for the plant.

Each of the seven large engines weigh 90,000 pounds, and each small engine weighs 35,000 pounds.

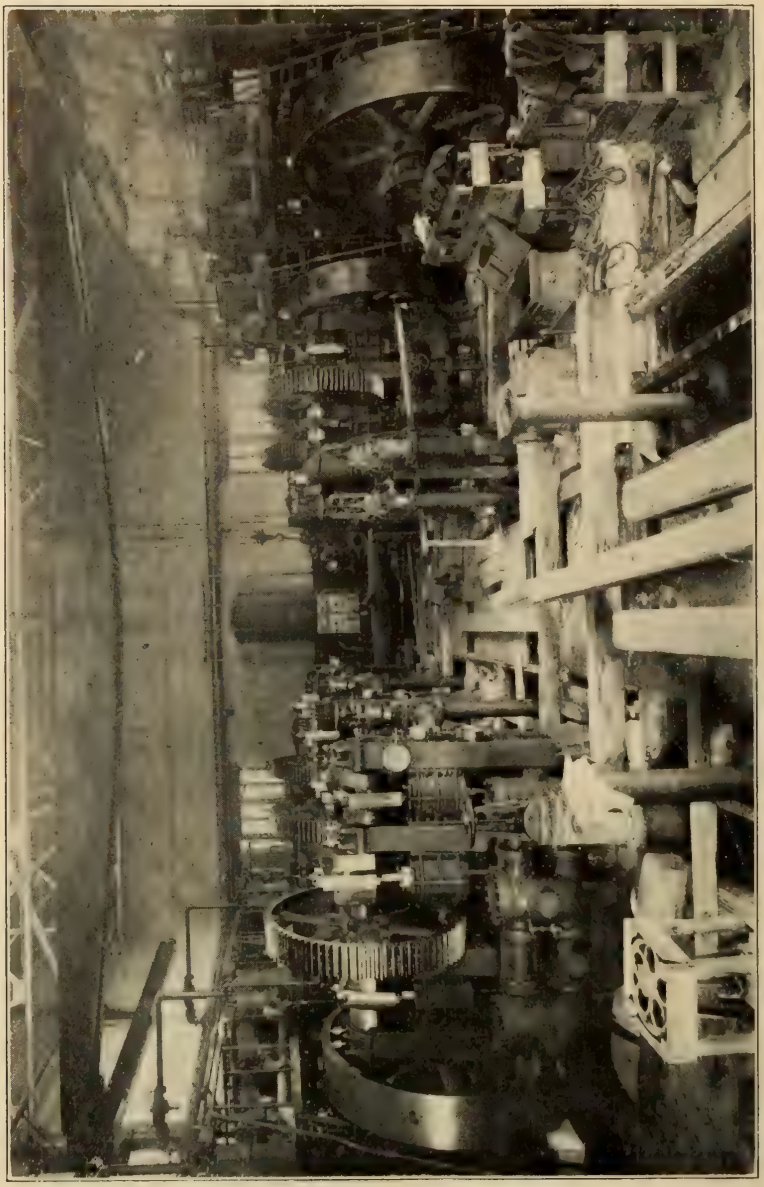
The pumps are double acting, triplex plunger pump, 11½x12 for large pumps and 6½x12 for small pumps. The combined delivery of entire plant averages 10,000 gallons per minute under pressure of 300 pounds per square inch. The pumps were all made by the Dean Pump Co., of Holyoke, Mass., each large pump weighs 49,000 pounds, and each small pump weighs 25,000 pounds. The contract price for installing the entire plant, namely, building, $32,000; nine gas engine units and pumps, two Rand Compressors, two 220-direct current generators, 8 air tanks, electrical work, etc, was $178,000, thus making a total for power plant, complete, $260,000.

The fuel used for operating the engines is gas, which is obtained from the United Gas Improvement Co. The supply of gas is well protected from failure. The supply to the station connects with every distributing station (seven in number) belonging to the gas company, thus providing for accidents to any one or number of their plants, even should gas holders give out at one or more of their distributing stations, gas can be obtained by by-passing said holders.

This certainty of the gas supply is a very strong feature of the station, as it obliterates defects of banked fires, etc., in steam plants, and electrical defects, either in conduits, dynamos, short circuits, etc., where engines and pumps are electrically driven, neither of which are usually re-layed. The essential feature of a central power station for fire fighting purposes is necessarily founded on the basis of assurety which literally means that more than one method must be in existence to accomplish the same result. In this respect the pumping station is very strongly fortified, thus rendering mechanical movements relayed in such a manner that entire failure is eliminated. The gas supply to the station is drawn from a 30-inch



High Pressure Fire Service, Philadelphia, Pa.—Pumping Station.



HIGH PRESSURE FIRE SERVICE, PHILADELPHIA, PA.—PUMPING STATION INTERIOR.

trunk main on Front Street, a distance of 150 feet from the power station.

A 16-inch supply main extends from the 30-inch main on Front Street to the interior of the station, this 16-inch main being controlled by a street valve on the south sidewalk of Race Street, distance 40 feet from station. For greater security it was thought best to locate this 16-inch main on the sidewalk, thus keeping it entirely free from disturbances arising from the street work done by the different corporations, and likewise protecting the pipe against settlements from traffic, sewer, cave in, etc.

From this 16-inch gas main leading into the station we have the gas lines leading up to the engines. These are 12, 10 and 8-inch lines. These pipes are all located along the walls, thereby rendering accidents happening to same from traveling crane very remote.

The average analysis of the gas supplied to the power station is as follows:

Carbon dioxide	2.89 per cent.
Oxygen	0.60 per cent.
Hydrogen	32.70 per cent.
Carbon monoxide	21.20 per cent.
Methane	26.30 per cent.
Nitrogen	4.70 per cent.
Illuminants	11.61 per cent.

The gas furnished averages 23 candle power, and is nearly uniform in quality and pressure. The average maximum pressure being 32/10 and the minimum pressure 22/10, the data being obtained from gas charts in the pumping station, which records (Bristol guage) the pressure every minute in the day.

The average calorific value of the gas is 675 B. F. U. per cubic foot.

Each engine receives its supply of gas from the supply mains located along the walls in the engine room (previously mentioned), and each engine is independently connected, thus enabling any engine and pump to be put out of service without interfering with the remainder of the plant.

All gas from the supply mains passes through the gas regulators attached to each engine and is supplied to each engine at nearly atmospheric pressure. All gas regulators are within

reach from the engine platform and can be readily adjusted at any time so as to maintain a zero pressure upon the engines. The pressure of the gas at the engine is indicated by a manometer gauge which is within reach and view of the engine operator, hence any defect in the gas regulator can readily be detected. A valve back of each regulator and the main throttle valve at the engine provides means for controlling the engine and removing the regulators for inspection if necessary. Ordinarily the former is left open in order to reduce the duties of the operator in starting. From the throttle the gas enters a combined mixing and governing valve which can be adjusted by means of graduated levers for the most efficient mixture of gas and air. This adjustment, when once made, need not be altered when the quality of the gas remains constant. The mixture on which all engines have been operated since the plant was installed is one part gas to six parts air. The admission and exhaust valves are plain discs, seating vertically in the direction of the internal pressure, hence very light mechanism is required to operate them. Cams are used for this purpose arranged on lay shafts geared to the main shaft. The upper lay shaft likewise operates the ignitors. Both sets of valves can easily be removed for inspection through the cylinder head. Those of the exhaust are water cooled to insure longer life.

The ignition of the mixture under compression is accomplished by an electric ignitor of the make and break type, removable for cleaning, in the form of a single plug; to render operations assured all engines are furnished with duplicate ignitors and by means of a throw-over switch the ignition current may be transferred to the reserve ignitor on any cylinder. Owing to the fact that the explosive mixture of gas and air reaches on combustion an average temperature of 2,600 degrees, it is necessary to use cooling water for cylinder heads, valves, and exhaust mains, otherwise the cast iron, whose melting point averages 1,800 degrees, would disappear. This cooling water is controlled by a single valve, and for assurety of cooling water the plant is capable of obtaining it from three different sources, each separate from the other. The relative amounts of water applied to the several parts of the engine are permanently adjusted by individual valves, and to prevent the

jackets from being drained when the plant is idle a water seal is fitted to each engine with a short stand pipe. This is open to the atmosphere, and serves as a tell-tale. If the overflow becomes stopped water will pour out of the vent, or if the engines after starting are allowed to run too long with a short supply of water, steam will issue from the vent. The flooding of cylinders from cooling water turned into the exhaust main is prevented by the drain pipe which connects directly with the sewer without an intermediate valve. The general slope of the piping forms a water pocket at its junction with the exhaust main.

In order to convey the spent gases from the engines after combustion takes place, cast iron pipe is used, which extends above the roof of the pumping station, and terminates in a cast iron exhaust head, which serves as a muffler and trap as before mentioned the traveling crane is free to move without interfering in any way with any of the pipe systems installed in the plant.

Air Storage.

All the engines are started through the agency of compressed air, which is stored at 200 pounds pressure. There are eight seamless steel tanks, each sixteen (16) inches in diameter by fifteen (15) feet long; these are all used to store up the compressed air. They are all connected by means of manifolds and separate valves, thus permitting any number of tanks to be used for service, whilst the remainder can be held in reserve. The total storage capacity for air amounts to 20.55 cubic feet for each tank, or a total of 164.40 cubic feet for the eight tanks. As to efficiency of air storage capacity it would be well to note that the entire plant of nine units were gotten under way with six tanks of air, thus leaving two tanks in reserve. This test was made by Dr. Lucke, expert for the underwriters, and proved conclusively that the air storage capacity was more than ample to get the entire plant under way without operation of either air compressor. It has been found by experiment that the amount of air required to start any individual unit depends upon the location of that unit with reference to the location of the storage capacity. The volume of air used varying from 70 pounds for the units located nearest the storage tanks, to 150 pounds for units located farth-

est from storage tanks. In order to render the storage capacity and volume of compressed air an assurety the tanks are tested daily, resulting in a trying out of both small engines and air compressors, and a maintenance of the full 200 pounds air pressure on each tank. The two air compressors are operated by means of the two 125 horse power gas engines, and each compressor unloads automatically when each tank contains the maximum air pressure. Compressed air, it will be understood, can always be maintained on the air supply lines to each of the engines, or can be kept stored in the tanks and delivered to the engines just before they are to be started in service. As the large units are gotten under way the small engine and air compressor is immediately started up, this operation again brings the tanks back to full storage capacity; in other words, the air used to get any number of units under way is immediately replaced; by this method personal error in air manipulation is always provided for. In addition to the starting of the engines, the air pipes connected to each engine are fitted with a 1¼-inch jet cock, the opening of this jet cock blows out all moisture existing in the air supply line.

The two small gas engines run in addition to the air compressors, two 7½ K. W. generators, both compressors and generators being belt driven from the small engines, and both small engines can be operated independent of the pump (pump connected to engine by aid of a clutch). These small pumps, as before mentioned, each discharge 350 gallons per minute under any pressure up to 300 pounds per square inch, and can be used more economically for saturation after a fire has been conquered than a large 1,200 gallon pump. As a comparison of cost, the small pump can be operated under 300 pounds pressure for two (2) dollars per hour, whilst the large pump for the same time operated would cost five (5) dollars per hour, thus meeting the emergency at a saving of three (3) dollars per hour.

As before mentioned the starting of the engines is accomplished through the agency of compressed air. As the pumps are arranged for starting without load, the work done by the engine is that of friction alone. Compressed air is first admitted to one cylinder, which acts as an air motor. In three revolutions the normal explosion cycle is started in the remain-

ing cylinders, the compressed air is then shut off and the exhaust valves are thrown into action in quick succession by the levers attached to the engine. In throwing the engine out of service the key-way on the fly wheel is set in proper position for another start by means of compressed air; in addition, the key-way can be set in proper position by means of a lever applied to the notches in the fly wheel, thus saving air should the occasion require it.

Ignition Current.

The ignition current constitutes one of the most vital points in gas engine operation. The assurety of the fuel supply, heretofore mentioned, must, for successful operation, be backed up with non-failing ignition currents, and likewise jacket water supply. Each engine is furnished with an ignitor cabinet located near the engine throttle upon the upper galleries, and three sources of current are available for ignition of the gas at each cabinet, and are there controlled by switches, first a 220-volt Edison current, taken from the street conduits, can be utilized and put through a rotary transformer; second, a current can be regularly supplied from a duplicate set of 7½ K. W. 220-volt direct current generators belted to the small engines (these generators are in duplicate). This voltage is reduced to 110 volts by individual motor generators. These two dynamos deliver their current to a main switchboard, from which lines are taken around the walls of the building to the ignitor cabinets, of which there are nine, one for each engine. On this main switchboard are also placed two switches connected to the Edison 220-volt main, one supply current to the ignitor cabinets, and the other to the nine motor-operated overflow valves, a description of which will be given later.

The third source of current supply is from the six cells of Edison Lalande primary battery type R. R. which are located inside of each ignitor cabinet. The Edison Lalande battery is connected to one end of a double throw switch, the center connections of which switch are taken respectively through a spark coil, to the ignitors on the engine, and to the metal of engine, so as to form a grounded return through the ignitor when this is closed. By placing the switch in the downward position the ignition is obtained from the primary batteries direct. When the switch is thrown in the upward position it

is connected to the middle point of a second double throw switch, one side of which is marked "Emergency Ignition," and the other side the "Regular Ignition." The emergency ignition side is operated by current taken direct from the 220-volt dynamo, through a bank of 220-volt 32 candle power lamps, three of these lamps in multiple being ordinarily used so as to give about 1½ amperes of spark current. In the regular ignition position the switch receives current at 110 volts from the secondary side of a small motor generator, which is set upon the top of the cabinet, the current passing through a similar bank of 110-volt 16-candle power lamps, three of these giving 1½ amperes.

The motor end of this motor generator is operated through the usual starting box, from the center of a third double throw switch which has its two ends connected, one to the 220-volt station dynamo, and the other to the 220-volt Edison mains. Thus these motor generators take current at 220 volts and deliver it at 110 volts. This gives the best results as to assurety of firing the gases, and at the same time results in the least wear upon ignitor points, and least leakage through the insulation of the ignitors. The inter-position of the double winding of the motor generator also keeps all grounds from the Edison circuit where this is used, and also prevents one unit interfering with another. The connections of all the cabinets are so arranged that when running in the emergency position and taking current from the small station dynamos, the same pole of the circuit will always be connected to ground or to ignitor, no matter how the switch may be placed or how many engines may be running.

As a guard against improper movement of switches on ignitor cabinets it may be well to state that everything about the cabinets is so arranged that the engine operator cannot by any combination of the switches get the Edison current and the station current thrown together or either of these into the primary battery. The wrong position of a switch may stop or affect the working of that particular engine, but cannot interfere with any other.

Electrical Operation on the Overflow Valves on Each Pump.

For operating the motors on the overflow valves, current is

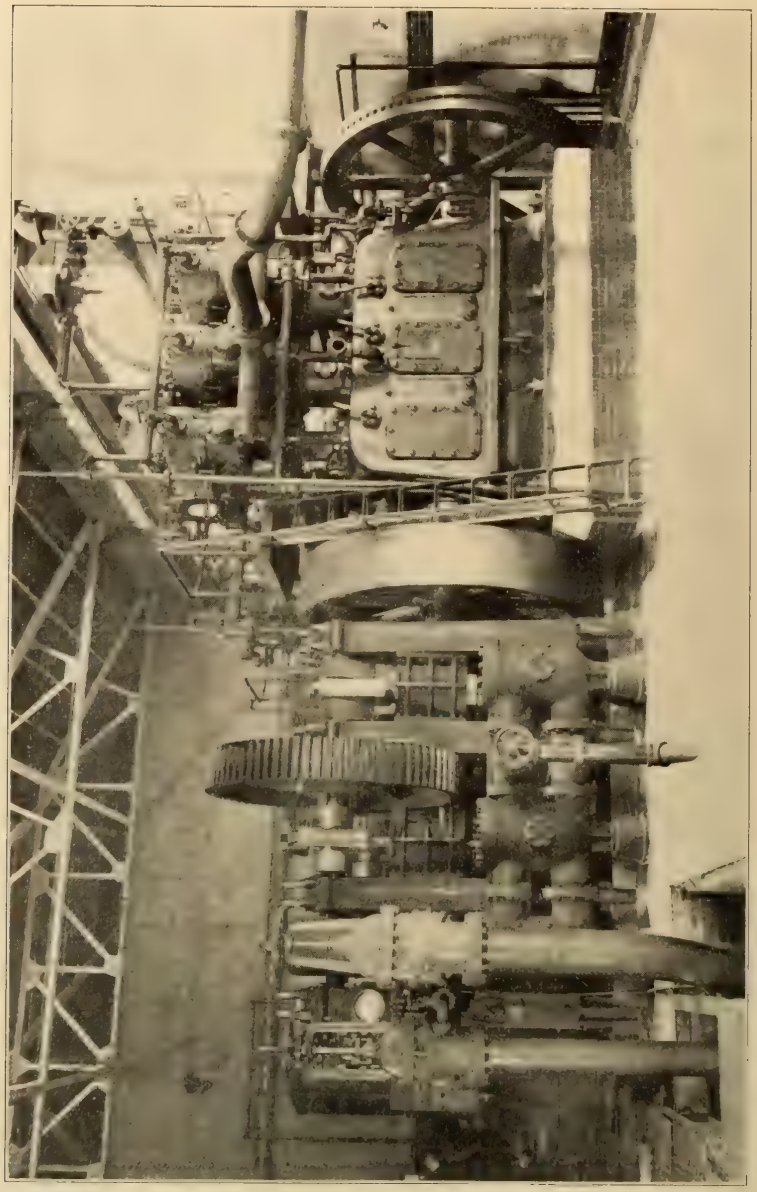
taken only from the Edison 220-volt circuit through the second switch (referred to above) on the main switchboard. From this switch the current is led to each of the pumps and there is taken through a reversing switch to a small ½-horse power series wound motor, connected by a train of gears to the overflow valve. By throwing the switch in or out the overflow relief valve can be set to any position and therefore operating the pump at any pressure desired, up to 300 pounds. Should the Edison current give out at any time provisions are made to operate all the overflow valves by hand. This operation can be applied collectively or to any single pump. The functions of this valve will be treated under pump description.

Pumps.

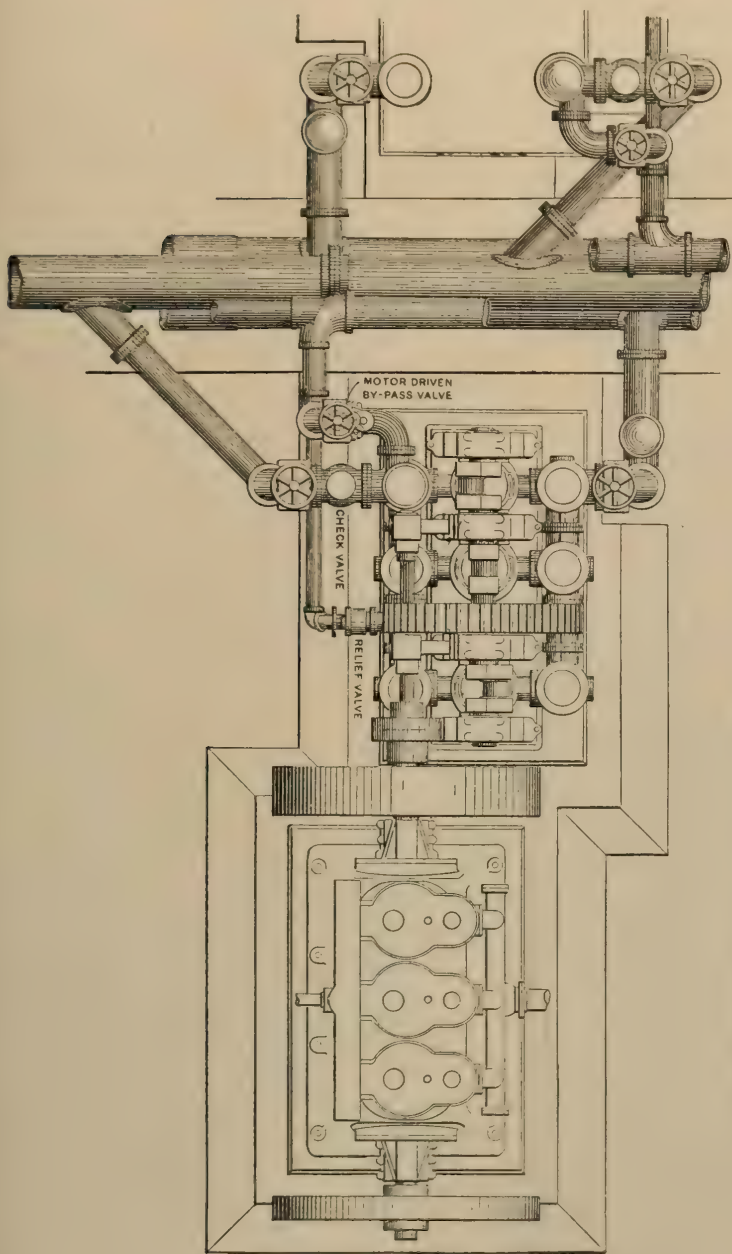
The pumping machinery was constructed to meet special specifications, in which a considerable improvement over standard practice was contemplated. The general design is that of the standard triplex, double acting, inside packed type of single geared plunger pump made by the Deane Co., of Holyoke, Mass. The large vertical direct double acting pumps are 11½x12, with a capacity of not less than 1,200 gallons per minute at 40 revolutions per minute, all pumps geared in a ratio of five to one. The small pumps are similar in design to the large ones, with 6¼x12-inch plungers, and each has a capacity of not less than 350 gallons per minute. The triplex design was selected because of the uniform discharge to be secured, which at the high pressure employed on the mains, becomes imperative; specially massive construction has been employed, together with composition bronze in all internal fittings to secure easy starting after a period of idleness.

The water ends are constructed in sections with unusually large valve areas. Suction and discharge boxes are cast separate from the pump barrels, which in turn are separate from the base.

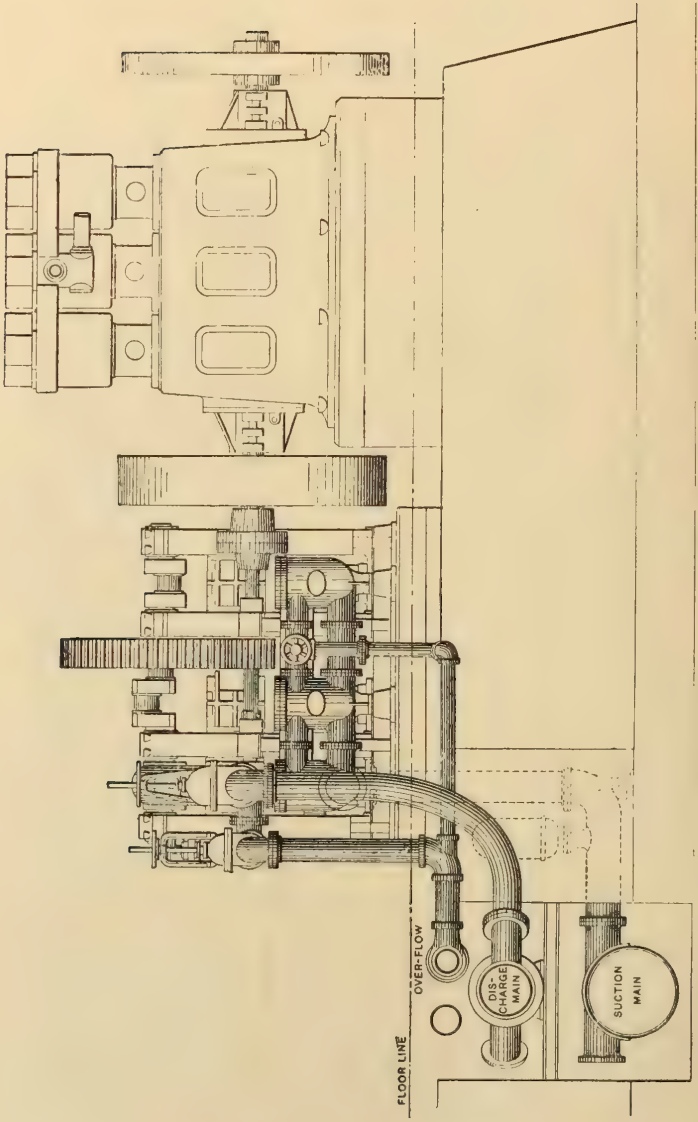
The three resulting sections of the pump are united by bolted flanges, and the replacement of any part may thus be accomplished without disturbing the adjustment of the remaining parts. All moving parts of the pump are adjustable to compensate for wear. A striking feature is the provision of a motor-driven by-pass valve controlled, as previously described, by means of an electric switch attached to the housing of the



HIGH PRESSURE FIRE SERVICE, PHILADELPHIA, PA.—INTERIOR ENGINE HOUSE.



High Pressure Fire Service, Philadelphia, Pa.—Plan of a Complete Pumping Unit.



High Pressure Fire Service, Philadelphia, Pa.—Elevation of a Complete Pumping Unit.

pump. When any unit is started this valve is left open, and when full speed is reached the motor valve is closed, which action diverts the discharge from the overflow pipe leading to the sewer to the discharge main connecting to the fire main system.

This operation allows the pump to start up under friction load, and the discharge pressure is gradually increased, to full working pressure during the closing of the valve, thus avoiding all shock to the machinery or system. It also does away with the friction clutch which otherwise would be necessary.

A permanent automatic relief valve is attached to each of the pumps. This is permanently fixed at the maximum load desired and can be set to relieve at any pressure. This relief is attached to the discharge chamber of the pump, which is fully protected against excessive pressure or from any back pressure thrown on the pumps from a sudden closing of a fire hydrant. The motor-driven valve is used to control the pressure between zero and the pressure at which the permanent relief is set. This enables the operator to respond instantly when a lower pressure is called for without touching the permanent relief valve. It likewise enables the operator to immediately throw off the entire pressure on the pipe system should occasion require it, without shutting down the unit.

There is a check valve in each discharge which protects an idle pump against back pressure from other units in operation. The suction and discharge to each pump is fitted with an air chamber.

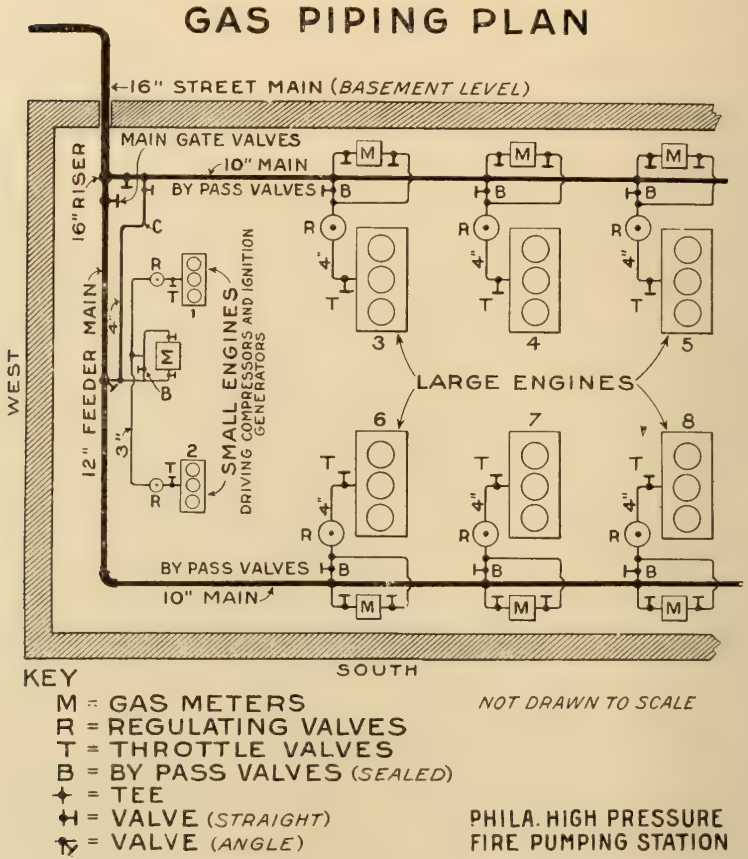
The water supply for the entire pipe system is fresh water obtained from the Delaware River. A three (3) feet steel suction pipe extends into the river at the bulkhead line, the bottom of this suction pipe being seven (7) feet below extreme low water mark, the end of which is fitted with a rod screen. The water passes through this suction pipe inside of building, and is there connected to each pump. The floor level of the pumping station is 13 feet above bottom of suction pipe in river, and 9½ feet above bottom of suction pipe in the building. The maximum lift is 20 feet, the minimum lift, 10 feet, as recorded by vacuum gauges on the pumps.

The well built inside of the station to receive the 3 feet steel suction pipe contains also every system of pipes installed in

the building, such as discharge main, suction and discharge connections to pumps, jacket water lines, sprinkler and electrical connections, etc., all of which can readily be reached by lifting the iron floor plates which cover the well. The above well thus affords an easy means of getting at all pipe joints without tearing up the cement floor in the engine room.

PUMP THRUSTS GAS ENGINE GOVERNING.

In the principle of regulation employed, no idle strokes are



admissible, as in the "hit and miss" governing. This arrangement of the valve mechanism is such that a charge of explosive mixture of constant and uniform quality is admitted to the cylinder at every other stroke, and is in turn ignited at the succeeding stroke. This secures a uniformity of effort upon

the crank shaft superior to that obtained by the other method.

The proportion of the power generated to the load upon the engine is performed by a centrifugal governor positively operated through gearing from the crank-shaft. The governor controls the admission of a variable quantity of mixture to the cylinders according to the load. For purposes of pump driving this method of governing is desirable, as through the uniformity of rotation heavy wear on the gears and sudden thrusts upon the incompressible water in pump cylinders is avoided.

Gas Consumption, Large 300 B. H. P. Engines.

With 300 pounds pressure on the large pumps each delivering 1,200 gallons of water per minute requires 280 B. H. P. on the engine. The consumption of gas per minute under these conditions was 83 cubic feet, or 4,980 cubic feet per hour for 280 B. H. P., or 17.79 cubic feet per brake horse power per hour equals 12,008 heat units. Cost of operation per brake horse power per hour, 1.78 cents.

With 200 pounds pressure on the pump gauge the total brake horse power is 186.67, consumption of gas per minute 75 cubic feet, or 4,500 cubic feet per hour, or 24.11 cubic feet per brake horse power per hour, equal to 16.274 heat units; cost of operation per brake horse power per hour, 2.41 cents.

With 100 pounds on the pump gauge the total brake horse power is 93.34; consumption of gas per minute, 52 cubic feet per hour, 3,120 cubic feet, or 33.43 cubic feet per brake horse power per hour, equal to 22,565 heat units. Cost of operation per brake horse power per hour, 3.34 cents.

Consumption of gas, no load, averaged 35 cubic feet per minute.

Gas Consumption, Small Engines, 125 B. H. P.

Small engines operating pump under 300 pounds pressure per square inch and discharging 350 gallons of water per minute requires 81.67 brake horse power, whilst the operation of the dynamo and air compressor (belt-driven off of small engine) requires an additional 15 brake horse power, making a total of 96.67 B. H. P. The consumption of gas per minute under these conditions is 34 cubic feet, or 2,040 cubic feet per hour, or 21.1 cubic feet per brake horse power per hour, heat units 14,243. Cost of operation per brake horse power per hour, 2.1 cents. Under a pressure of 200 pounds on the pump gauge

including operation of dynamo and compressor, requires 69.45 B. H. P. gas consumption per minute, 26 cubic feet, or 1,560 cubic feet per hour, or 22.46 cubic feet per B. H. P. per hour, heat units, 15,161. Cost of operation per brake horse power per hour, 2.25 cents.

Under a pressure of 100 pounds on the pump, together with operation of a dynamo and compressor, requires 42.22 B. H. P. Gas consumption per minute 22 cubic feet, or 1,320 cubic feet per hour, or 31.26 cubic feet per brake horse power per hour, equals 21,101 heat units. Cost of operation per brake horse power per hour, 3⅛ cents.

With pump out of service and small engines operating on dynamos and air compressor, requires 15 B. H. P. Gas consumption per minute 17 cubic feet, or 1,020 cubic feet per hour, or 68 cubic feet per brake horse power per hour, heat units, 45,900. Cost of operation per brake horse power per hour, 6.8 cents.

Operating Expenses For 1904.

Total hours run, large engines, 337 hours 3 minutes; total hours run, small engines, 197 hours 24 minutes; load on large pumps, 100 to 300 pounds water pressures; small engines run without load.

Total gas consumed for the year, 1,741,254 cubic feet, at one dollar per thousand. Cost, $1,741.25.

Gas consumed under following conditions:

Official tests	778,749 cubic feet
Oil tests	172,566 cubic feet
Plant in service 9 times	145,113 cubic feet
Plant started on 32 alarms (service not required)	48,357 cubic feet
Experimental runs, compressing air, etc.	596,466 cubic feet
Total gas consumed	1,741,254 cubic feet

Total gallons of water pumped	27,110,200
Pea coal used in boiler for heating building, 126½ tons @$3.73 per ton. Cost	$471.85
Electric lighting, Edison current	814.20
Electric ignition on engines, Edison current	21.80
960 lbs. No. 1, white waste @7½c	72.00

Graphite and tallow for pump gears, 60 lbs. @ 7c	4.20
Gasoline for ignitors, etc., 12 gallons @ 10c	1.20
Cost of oil for engines and pumps	270.55

Cost of oil represents filling all crank cases in 1904.

Cost of oil, 1905, nothing.

SUMMARY OF OPERATING EXPENSES.

Gas for engine operations	$1,741.25
Coal	471.85
Electric lighting and power	836.00
Oils	270.55
Waste, grease, gasoline	7.07
Repairs to machinery	1.57
Furnishing office, floor coverings, beds, bed linen, tools, etc.	700.00
Total operating expenses	$4,098.72

SALARIES OF STAFF.

Superintendent	$2,000.00
Two engineers, each $1,200	2,400.00
Four oilers, each $720	2,880.00
One mechanic, $900	900.00
One janitor, $600	600.00
Total	$8,780.00

Salaries	$ 8,780.00	
Operating expenses	4,098.72	
Total annual cost	$12,878.72	year 1904

Note the total annual cost of maintenance for year of 1905 was $12,000.00.

ECONOMY OF THE GAS ENGINE SERVICE FOR HIGH PRESSURE FIRE DUTY.

The economy of the high pressure fire service was clearly demonstrated at two conflagrations during the first year of its installation.

On September 18, 1904, the plant was put in action on Alarm Box 26, 8th and Market Streets, right in the heart of the congested district. Figuring on the basis of one engine the following data is given:

Hours run on basis of one large engine, 2 hours, 8 minutes; hours run on basis of one small engine, 0 hours, 21 minutes.

Amount of gas used, 7,872 cu. ft. @ $1.00 per M.	$7.87
Three gallons of oil @26c.	.78
One and one-half pounds of waste @7½c.	.11
Wages one engineer one-half hour.	.14
Wages two oilers one-half hour each.	.17
Total	$9.07

Constant pressure on the pumps 200 pounds; gallons of water pumped, 153,600; cost per thousand gallons, 5 9/10 cents.

The second conflagration was on December 19th, 1904. Alarm box 576, location 10th and Walnut streets.

Hours' run on basis of one large engine, 19 hours, 6 minutes. Hours' run on basis of one small engine, 2 hours, 24 minutes. Maximum pressure on the pumps, 225 pounds. Minimum pressure on the pumps, 75 pounds.

Amount of gas used, 75,893 cubic ft., at $1.00 per M.	$75.89
Six gallons of oil, at 26 cents.	1.56
Four pounds of waste, at 7½ cents.	.30
Wages, one engineer, 7 hours.	1.96
Wages, two oilers, 7 hours each.	2.38
Total	$82.09

Total gallons water pumped, 1,375,200; cost per thousand gallons, 6 cents.

Note the cost of pumping has not exceeded six cents per thousand gallons on all fires during the year of 1905.

Staff, Pumping Station.

Superintendent; Two engineers, two oilers (one engineer and two oilers 24 hours on and 24 hours off); one mechanic (mechanic daily, 8 hours); one janitor (janitor daily, 10 hours). Each engineer keeps daily log. Records: (a) Reading gas meters three times a day. (b) Pump counter readings, three times a day. (c) Pressures and temperatures, three times a day. (d) Electric light and power meter, three times a day. (e) Alarms, services and general occurrences.

Every day the following tests are made: (a) Electrical currents. (b) Cleaning and trying out ignitors. (c) General

examination of engines and pumps. (d) Individual engines turned over 5 to 15 minutes' run. Engines and pumps cleaned daily. Entire plant turned over once per week. Every ignitor cleaned once in three months. The three ignition currents tried before and at every fire service. Air always pumped up immediately after starting first engine.

STATION.

Entire station put under way in 7 minutes.

Full pressure on pump, 300 pounds, in 45 seconds.

Average starting time, per unit, 1 minute.

Compressed air starting system fully adequate.

Each compressor able to run one large engine continuously, independent of storage tanks.

Total air pressure drop in starting 9 units, with the compressor out, 97.9 pounds average, initial 200 pounds.

Time required to place on ignitor, 4 minutes.

Gas supply clean, uniform and continuous.

Cost of power approximately proportionate to pumpage.

Total operating cost averaged 12½ cents per 1,000 gallons pumped.

Cost at a large fire, 6 cents per 1,000 gallons pumped.

SYSTEM.

Entire plant capable of supplying fifteen 1½ inch streams that may be concentrated on any block within the congested or protected district.

Special water battery wagon can handle six (6) 3½ inch lines of hose.

Average station pressure for an ordinary fire, 200 pounds.

Pressure drop in 3½ inch hose about 20 pounds per 100 feet.

OPERATION.

Upper platform, close ignition switch, open engine throttle.

Lower platform, throw compressed air valve, throw exhaust valves, turn on cooling water.

Main aisle: Open suction valve, close motor switch on by-pass valve.

Making seven operations to be performed in getting one unit under way.

In considering the pipe system, much care was exercised. Steel flanged pipe, cast iron flanged pipe, and extra heavy bell and spigot pipe all received careful study, along all lines.

The available appropriation would not permit the use of steel mains; its cost was excessive compared with the use of cast iron. Bell and spigot pattern of cast iron pipe was abandoned, owing to the multitude of lead joints, thus increasing the liability to leakage through bad caulking of joints, or through such a pressure as 300 pounds per square inch. A decision was finally made in favor of cast iron flanged pipe with a solid lead sleeve introduced every 250 feet (see plans). In adopting this I feel we have used good judgment, as we have not had one defect develop in the entire 8½ miles of pipe system since it was put into service, three years ago.

Although the entire system has been subjected to a pressure of 300 pounds per square inch a great many times, in some cases for a steady period of five hours, and again is constantly subjected to pressures varying from 50 to 300 pounds at almost all conflagrations, dependent on fire department manoeuvers, increasing or decreasing the lines of water in service, etc.

In designing the pipe service provisions were made for three (3) fire boat connections along the Delaware River front, and six ways of circulating water, together with the introduction of many valves, so that in case of accident a minimum amount of the service would be thrown out of commission. Again, in laying the service a minimum depth of 7 feet was adhered to, the idea in this being to get below all service connections into buildings, etc., thus placing ourselves beyond disturbance in this direction. At the same time it gave us solid ground for pipe laying. (See plan of pipe service.)

It will be understood that the three fire boat connections shown on plan actually act as a relay water supply to the pipe system, and which is entirely independent of the pumping station. All sleeve and valve boxes are built large enough to permit any work in connection with sleeves or valves to be done without tearing up the street.

As before mentioned, all pipes and fittings were subjected to a pressure of 800 pounds per square inch (water) before accepted at the foundry, then when laid all pipe were again subjected to a water pressure of 400 pounds per square inch of water pressure to test accuracy of bolt joints and caulking on sleeves, stuffing boxes on valves and connections to hydrants.

etc., the portion of the line thus tested was then filled in and the ditch repaved.

The cost of installing the 8-inch pipe lines per foot, complete with valves, hydrants, sleeves, etc., $3.05 per foot.

The cost of installing the 12-inch lines per foot, complete with valves, sleeves, hydrants, etc., $6.00 per foot.

The cost of installing the 16-inch line, per foot, as above, $6.20 per foot.

Attention is called to the contract price per foot for laying the 12-inch pipe (cast iron). It will be noticed it is excessive compared with the 8 and 16-inch mains. The reason for this is due to the fact that the 12-inch pipe lines represent 60 per cent. of the entire service, and in laying this the contractor placed his price per foot to cover the cost and maintenance of paving over the entire system, which paving had to be kept in good order for a period of five years after completion of contract, 80% Belgian block and 20% asphalt.

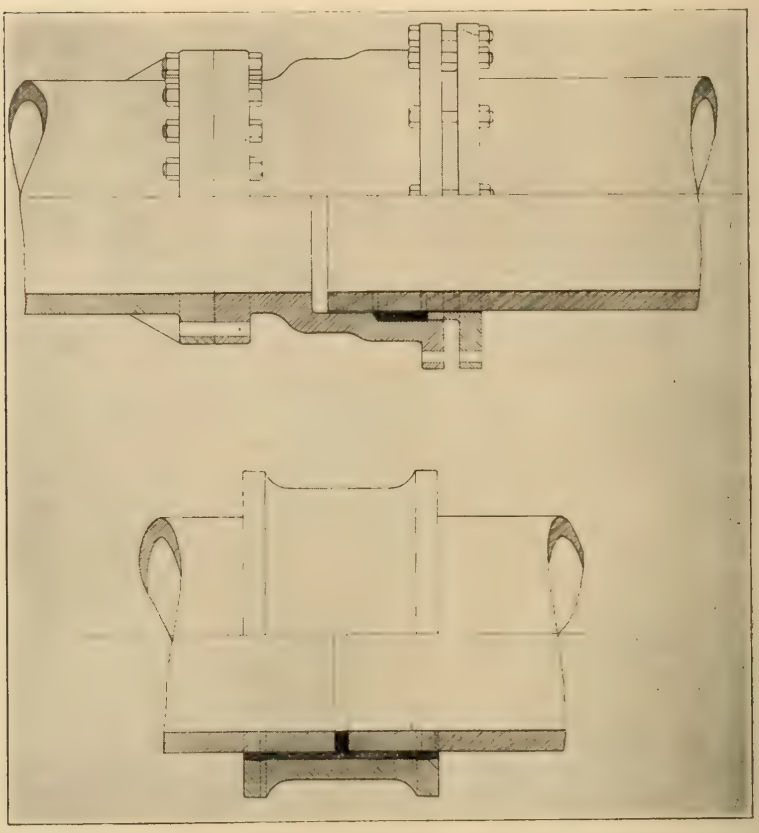
COST OF PIPE, ETC.

For furnishing cast iron stop boxes	$ 14.00 each
For furnishing and placing 1-inch air valves and extension stop boxes	7.00 each
Furnishing fire hydrant	110.00 each
Furnishing fire boat connections	925.00 each
Earth Excavation, bet. 8 and 12 ft. deep	1.38 per cu. yd.
Earth Excavation, bet. 12 and 16 ft. deep	2.31 per cu. yd.
Earth Excavation, bet. 16 and 20 ft. deep	4.40 per cu. yd.
For laying 8-inch steel main	.92 per lin. ft.
For laying 12-inch steel main	2.85 per lin. ft.
For laying 16-inch steel main	1.10 per lin. ft.
For laying 8-inch cast iron pipe	1.05 per lin ft.
For laying 12-inch cast iron pipe	3.05 per lin. ft.
For laying 16-inch cast iron pipe	1.35 per lin. ft.

PROPOSALS; PIPE LINE.

For furnishing 8-inch flanged steel pipe	$2.50 per ft.
For furnishing 12-inch flanged steel pipe	4.00 per ft.
For furnishing 16-inch flanged steel pipe	6.13 per ft.
For furnishing 8-inch flanged steel curved pipe	5.70 per ft.
For furnishing 12-inch flanged steel curved pipe	8.86 per ft.
For furnishing 16-inch flanged steel curved pipe	12.20 per ft.
For furnishing 8-inch flanged cast iron pipe	1.68 c. per lb.

For furnishing 12-inch flanged cast iron pipe.... 1.68 c. per lb.
For furnishing 16-inch flanged cast iron pipe.... 1.68 c. per lb.
For furnishing 8-in., 12-in., 16-in. cast iron special castings (all curved pieces, and pieces under 12 feet) .... 5½ c. per lb.
For furnishing semi-cast steel tees and crosses... 7 c. per lb.
For furnishing 8-inch flanged gate valves....$42.50 per valve
For furnishing 12-inch flanged gate valves.... 72.25 per valve
For furnishing 16-inch flanged gate valves.... 145.00 per valve
(16-inch valves provided with 3-inch by-pass.)



High Pressure Fire Service, Philadelphia, Pa.—Expansion Sleeves for Fire Mains.

To some the above mentioned prices may seem high, but as one familiar with the entire situation, I should say it was the most difficult piece of pipe laying in the country, extending as it did entirely through a very active congested district, where every foot of the work had to be guarded and traffic maintained at all times. All local contractors were tardy about entering a bid.

In fact, only two bids were received, although the total contract amounted to over $400,000.

20-Inch Pumping Main.

The 20-inch cast iron flanged pumping main is laid on Water Street from Race Street to Market Street, and connects with the pumping station at Delaware Avenue and Race Street.

Total pipe laid, 1,500 feet; total cost, complete, $24.00 per foot. This pipe was laid under a supplementary contract, after the other portions of the system was completed, (built and completed during the erection of pumping station).

The price bid was 3½ cents per pound, or double the price bid for the main system. The total cost of installing entire pumping main was $36,000.

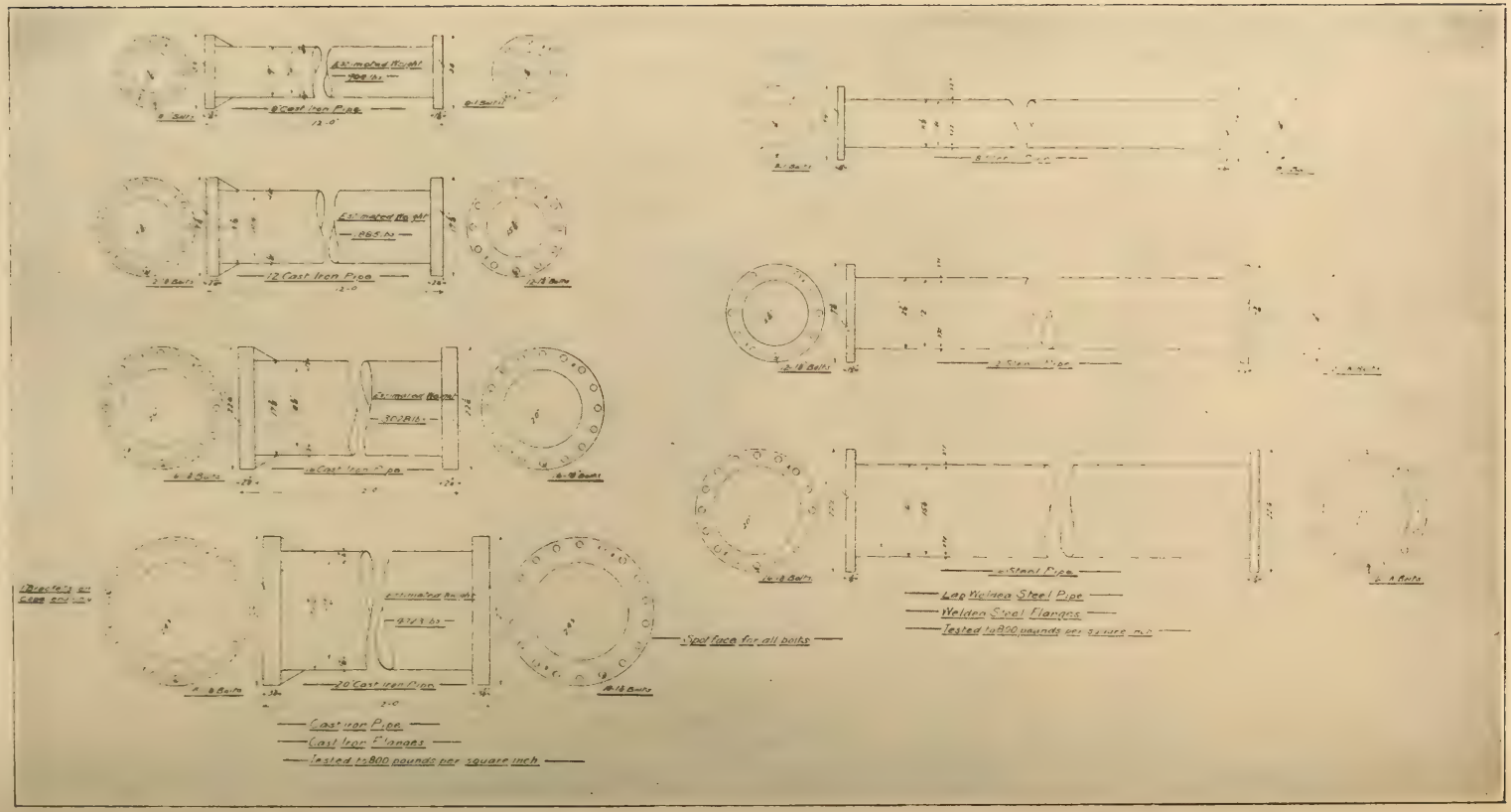
Weights of Pipe.

8-inch flanged cast iron pipe	81 lbs. per ft.
12-inch flanged pipe	161 lbs. per ft.
16-inch flanged pipe	260 lbs. per ft.
20-inch flanged pipe	390 lbs. per ft.

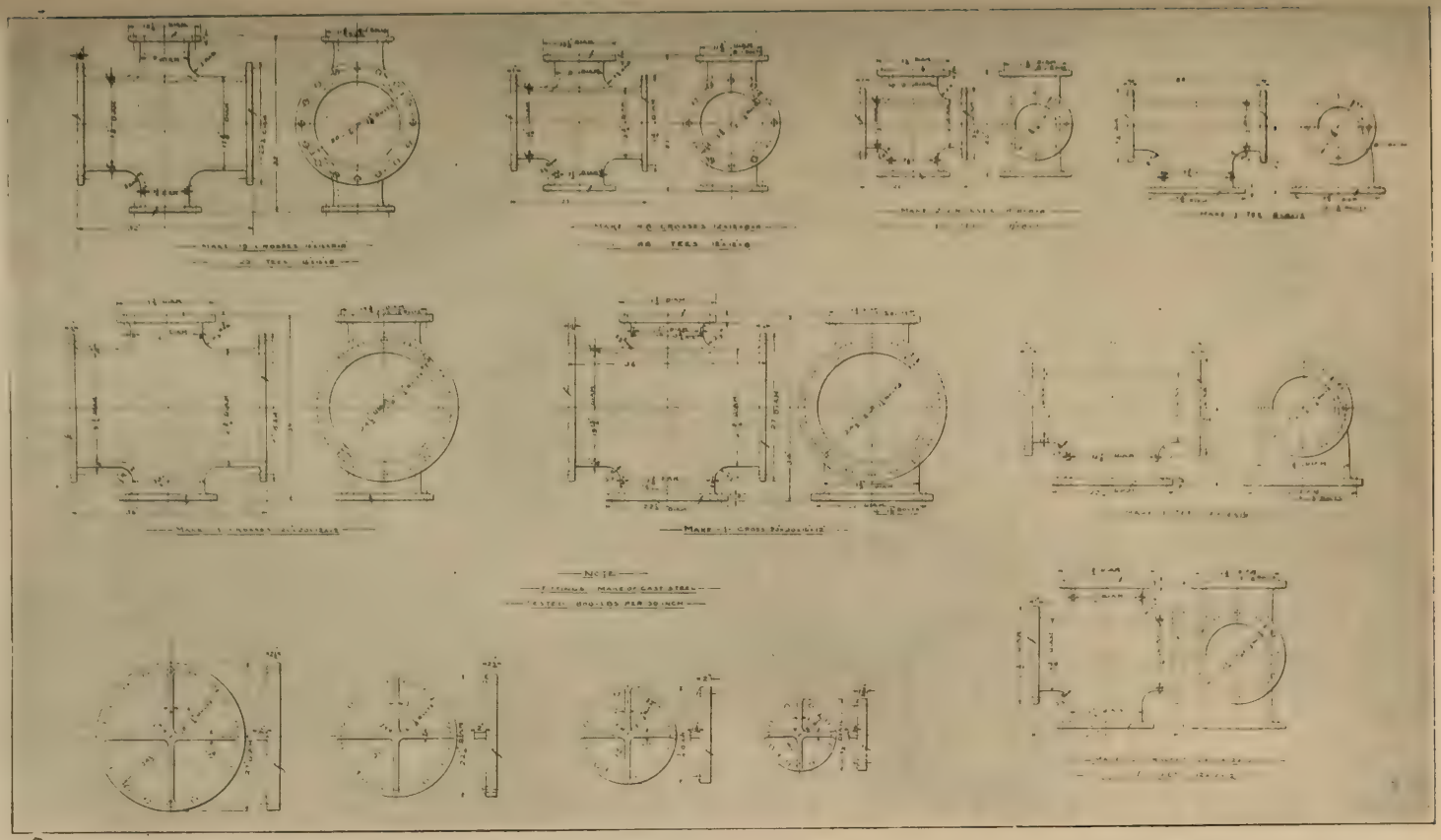
All pipe were handled by means of stiff legs and chain hoists, wherever possible, from three to four lengths of pipe were bolted on the high level and when completed were lowered in the ditch as one pipe. This method of laying was found to expedite the back filling of ditches. Total time consumed in laying the entire system, complete, two years.

And the total expenditure for pumping station and pipe system, ready for service, was $750,000, a price we consider as reasonably fair.

As soon as the high pressure system was finished the fire department was taken in hand in order to drill the men under the new order of things, and likewise test all their appliances, such as hose, nozzles, couplings, etc. A series of tests were given every week with water thrown into the river opposite the pumping station. These exhibitions were made to make



High Pressure Fire Service, Philadelphia, Pa.—Crosses and Tees.



High Pressure Fire Service, Philadelphia, Pa.—Cast Iron and Steel Pipe.

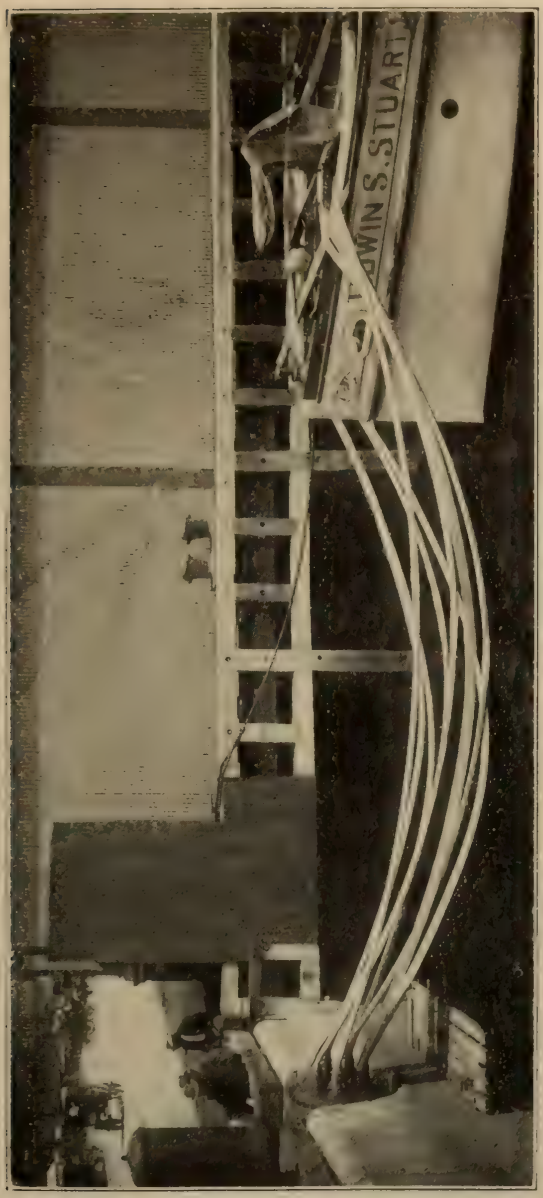
the men of the fire department familiar with this new fire-fighting medium, and in making these tests it was found that the old-time method of handling hose nozzles in throwing a stream of water where maximum pressure from the average steam fire engine rarely exceeds 125 pounds, would not answer at all for the new pumping station, with is delivery and pressure maintained at 300 pounds per square inch; hence to invite the confidence of the firemen in the use of high pressure streams, Mr. John W. Weaver, my constructing engineer of the high pressure system, designed a water battery capable of taking care of any pressure the station is capable of putting on the pipe lines. This battery has completely solved the problem of handling hose nozzles under all pressures, and has given much satisfaction in the fire department. For low pressure use an ordinary stake with steel prongs is used. Mr. Weaver then turned his attention to the quality of hose, couplings, nozzles used in the fire department, and has made tests lasting through an entire year, the result of which has been to increase the efficiency of the entire department. Mr. Weaver, on the strength of these tests, has issued a specification on which the fire department equipment has been purchased for this year.

The successful competitor was the B. F. Goodrich Co. Prices, 75 cents per foot for 2½-inch hose, and $1.40 per foot for 3½-inch all cotton rubber lined hose and guaranteed for four years. In addition to the above, Mr. Weaver is at present testing the merits of cotton versus rubber hose in the department, the results of which cannot as yet be determined.

Mr. Weaver is the superintendent of the high pressure system, and communications in the future regarding this system will be cheerfully answered by him.

It will thus be seen from the above that a high pressure system is likened to a well organized army, for instance, the artillery is the pumping station, the cavalry the pipe line system, and the infantry the fire department. Therefore, as a chain is no stronger than its weakest link, so all three branches of service for successful operation must necessarily reach a high grade standard of efficiency.

I believe it to be only a question of a few years when the



HIGH PRESSURE FIRE SERVICE, PHILADELPHIA, PA.—FIRE BOAT CONNECTIONS.

steam fire engine will be abandoned in large municipalities, and central power station system will be in advance. Even in small towns this is absolutely possible and economical with the use of the gas engine working with illuminating gas, gasolene, or by aid of a producer. Of course, a gas engine is not a commercial possibility when operating on illuminating gas at $1.00 per M., and running 8 or 10 hours every day. It is, however, possible with the aid of a producer, or natural gas.

There are to-day numerous small towns throughout the United States that should consider with favor the gas engine proposition with a view towards a combined distribution and fire system, procuring their water supply from artesian well system. Take, for instance, small towns of from 3,000 to 5,000 inhabitants, with the artesian well system. Two gas engines of 50 horse power each attached to pumps could readily and very economically fill a stand pipe 125 feet high by 30 feet in diameter, and maintain an efficient supply by operating only 12 hours out of the 24 as is usual with steam plants, and far more economical. The stand pipe system alone furnishing supply and pressure fully ample to take care of distribution. The supply to stand pipes being cut off in case of conflagration, and a 100-pound pressure can be obtained for fire purposes directly through the distribution mains. Such a problem could readily be solved and be economical, as it would dispense with the steam fire engine and render at the same time more efficient service.

The Philadelphia pumping station, as before stated, was to equal in capacity twenty steam fire engines with a capacity of 10,000 gallons of water per minute. We have done this at a cost of $177,000, and what is better still, we maintain it annually for two thousand dollars less than it costs to maintain one fire company of 12 men.

CHEESMAN DAM.

By Geo. T. Prince.

The Platte River has been facetiously referred to by a prominent writer as being three-fourths of a mile wide and three-fourths of an inch deep.

This stream is one of the largest tributaries of the Missouri River, into which it flows at Plattsmouth, Nebraska, about eighteen miles south of Omaha. (Plate 1.)

It is formed by the junction of the North Platte and South Platte rivers at North Platte, Lincoln County, Nebraska, from which point it flows eastwardly across Nebraska to its aforesaid confluence with the Missouri River at Plattsmouth.

The North Platte River rises in Northern Colorado, flows northwardly into Wyoming, and thence eastwardly into and through Nebraska. The South Platte River rises in central Colorado, flows northwardly then eastwardly to its junction with the North Platte River at North Platte, Nebraska. It is formed by the junction of the North Fork and South Fork at South Platte, Colorado, which point is located about thirty miles south of the city of Denver.

Cheesman Dam is located on the South Fork of the South Platte River about twenty miles south of the point of junction of the north and south forks of the South Platte River and immediately below the point where Lost Park Creek, otherwise known as Goose Creek, flows into the south fork of the South Platte River. (Plate 3.)

It is a site most propitious for the building of a dam. The contour of the surrounding country is bold and rocky, there being but little vegetable growth, admitting of the storage of water to great depth.

It will be noted from Plates 4 and 5 how rocky and precipitous are the slopes of this lake and what ideal conditions are present for a reservoir site.

The gorge spanned by Cheesman Dam is formed by granite cliffs—sound and well adapted for storing water. (Plate 8.) Evidences are found along the granite slopes of the South Platte River above the dam indicating the former existence of a natural dam at or near the location of Cheesman Dam, which had stored water to a much greater height than does the pres-

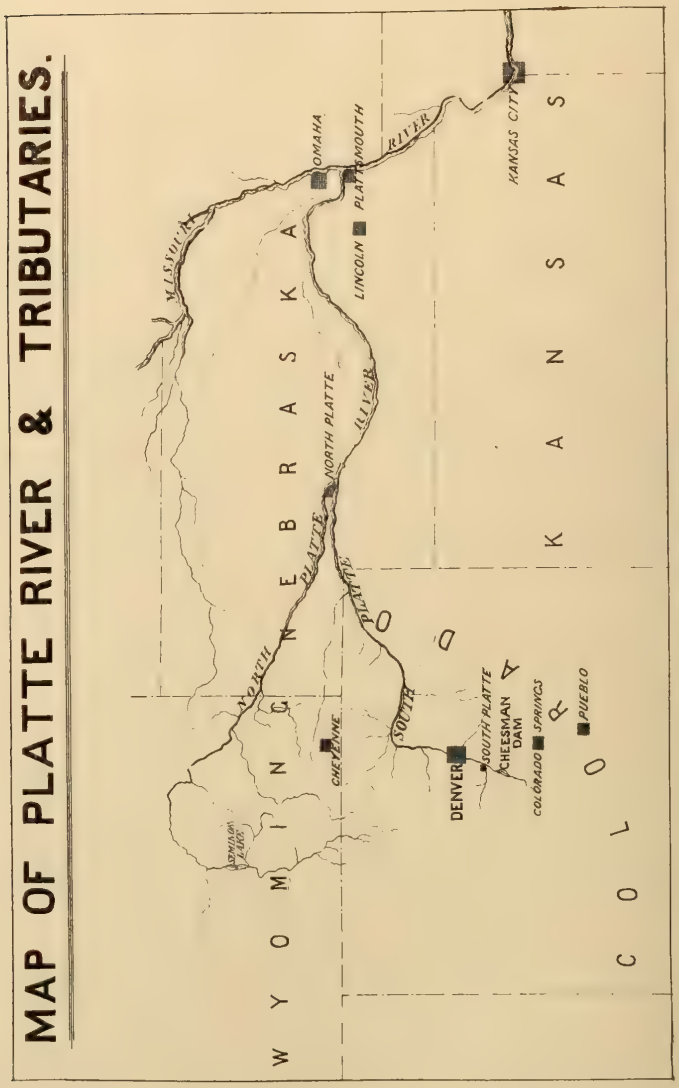


Plate 1. General View of Platte River, Showing North and South Branches.

Plate 3. View of Mouth of Goose Creek, Looking South Toward Dam.

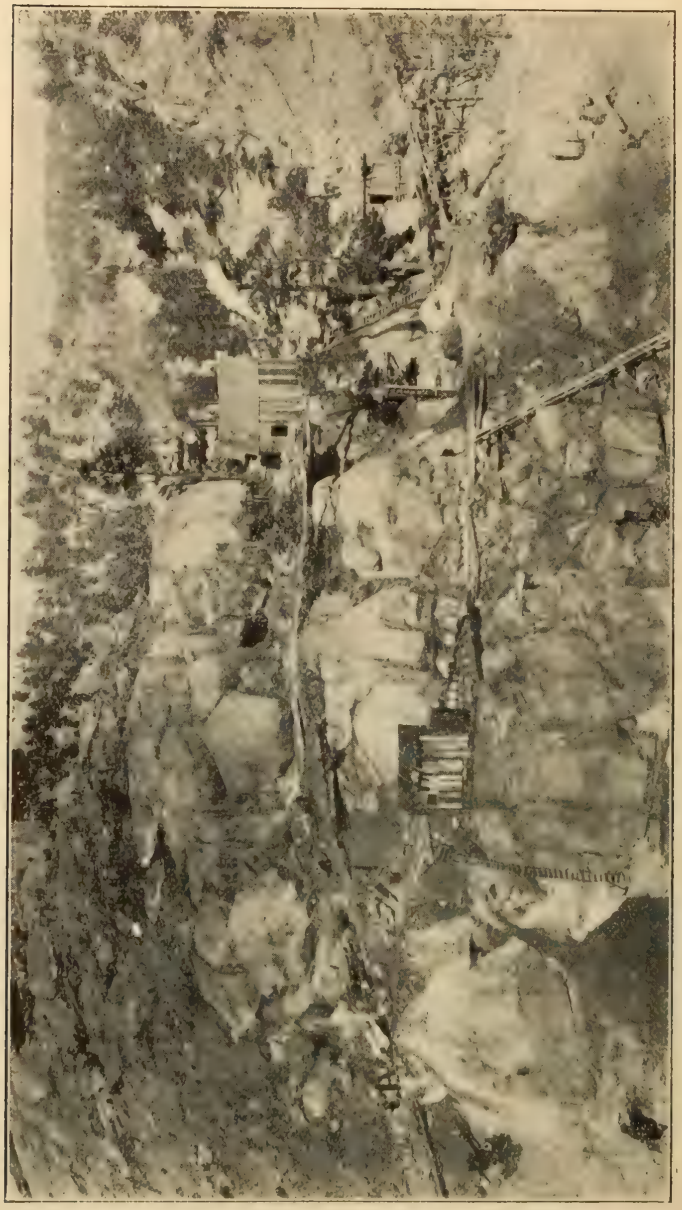


Plate 4. View of Dam Site, Looking East, Showing Inlet Portals at Elevations 60 and 104.7.

PLATE 5. PARTIAL VIEW OF RESERVOIR SITE FROM DAM SITE, LOOKING WEST.

ent structure. Either this was the case or the river has gradually, through the ages, worn its channel deeper and deeper through its granite bed, hundreds of feet, leaving water holes far up the side of the ravines.

The water shed which drains into Lake Cheesman embraces 1,796 square miles and is located as shown upon Plate 10, which has been compiled from maps prepared by the U. S. Geological Survey. This water shed comprises a country in the Rocky Mountains almost entirely devoid of population and other sources of stream pollution.

At the dam, the gorge is very narrow, being about 30 feet at the level of the river. The datum to which all elevations about the dam and lake are referred is the former low water in the river at the site of the dam, which elevation is 6,644 feet above mean tide level.

At elevation 30 the gorge is about 40 feet in width and at elevation 90 it is about 130 feet, above this elevation the slopes of the canon are about 2¼ feet horizontal to 1 foot vertical.

At the location of the dam the stream flows toward the east, the dam lying nearly north and south.

The spillway, which is built upon a natural depression of the hill to the north of the dam, will be referred to later.

Cheesman Dam was designed by Mr. Chas. L. Harrison, former chief engineer of the Denver Union Water Company, assisted by Messrs. Alfred Noble and L. E. Cooley as consulting engineers.

The cross-section of the Cheesman Dam is shown by Plate 13. The dam as thus constructed is sufficiently strong to sustain the pressure of a full reservoir, but owing to the location favoring a curved type, the dam was constructed upon a curve of 400 feet radius.

Plate 14 shows the plan of the dam and surroundings.

The natural foundation offered for the building of the dam was good. The river bed and the underlying stratifications were of sound granite and this applied to the rock sides up to elevation 30. Above this elevation more or less loose rock was encountered, necessitating its removal to a depth which insured a firm and satisfactory foundation. (Plate 17.)

PLATE 8. VIEW OF GORGE AND SITE OF DAM, LOOKING EAST AND DOWN STREAM, SHOWING CHARACTER OF SLOPES.

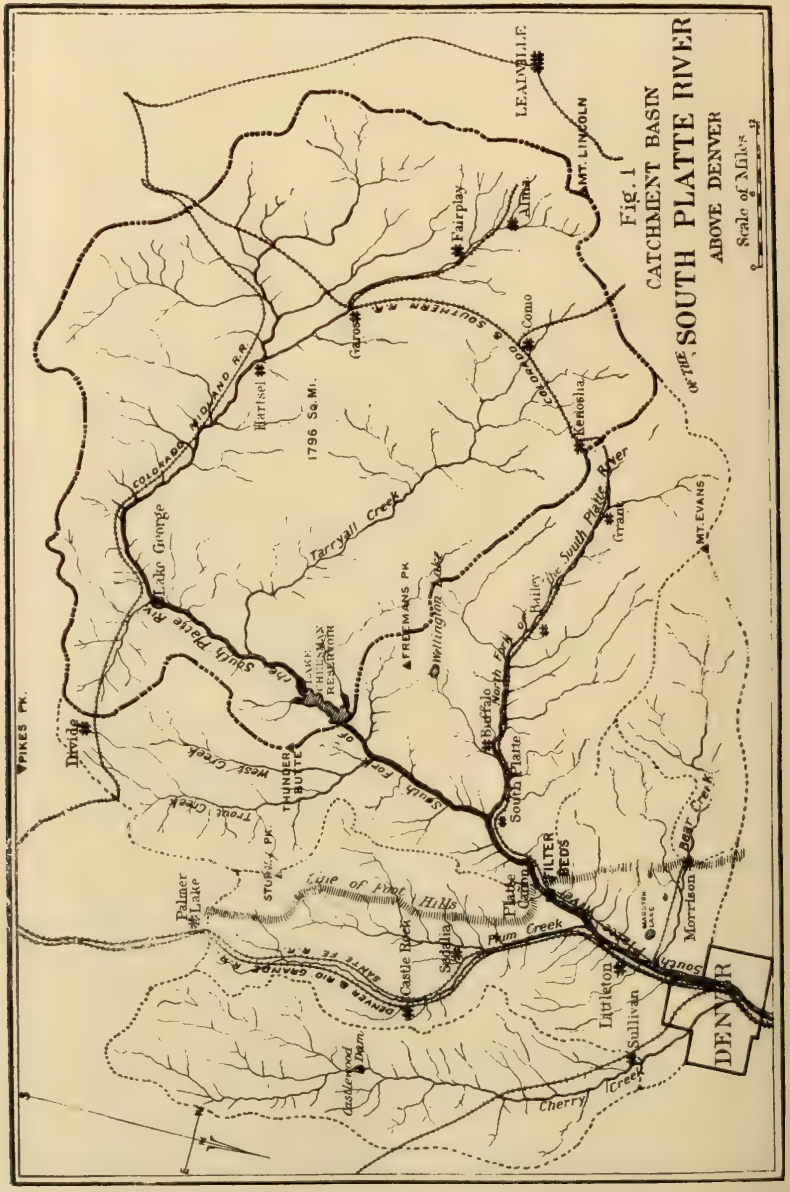


Plate 10. Plan of Catchment Basin of the South Platte River Above Denver.

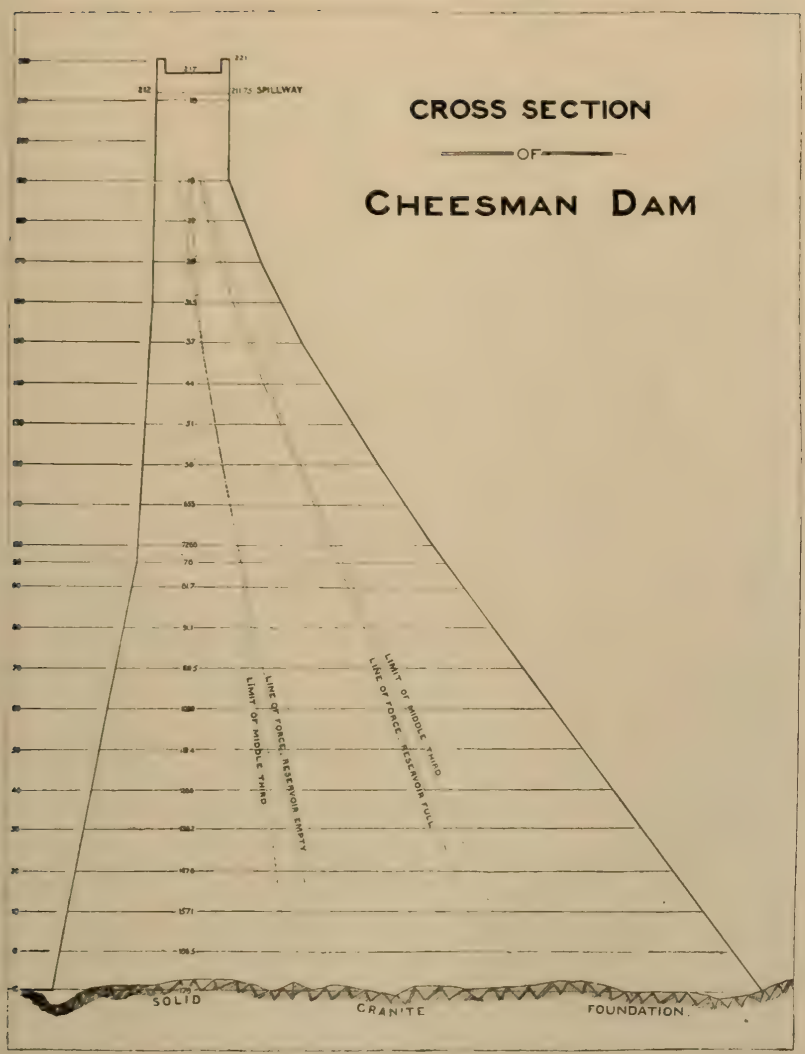


PLATE 13. CROSS SECTION OF CHEESMAN DAM.

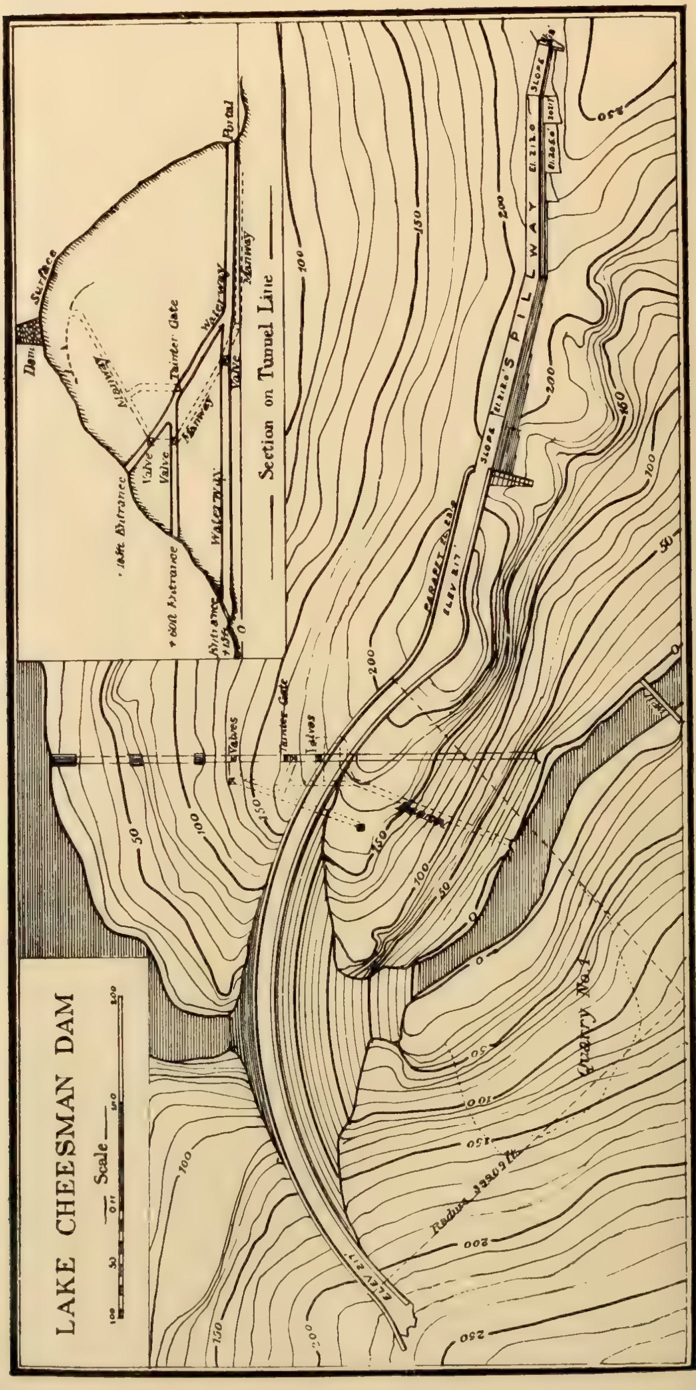


Plate 14. Contour Map of Cheesman Dam, Spillway, and Immediate Surroundings, Also Section of Dam and Mountain Beneath on Tunnel Line, Showing Location of Regulating Valves.

The dam is constructed of granite which was quarried near-by. That which was put in the up-stream face was obtained from the eastern side of the lake about 2,000 feet north of the dam, and was carried to the dam on barges, the water of the lake affording means for this method of transportation.

The stone for the downstream face came from a quarry immediately below the dam on the southern side of the gorge and was carried to the dam on cars shown in Plate 20.

The stone is of good quality, of a pink shade, and with its proper portion of mortar weighed when dry about 158 pounds per cubic foot.

The stones for the upstream face were rough pointed, the edges being cut to the curvature of the dam. They were laid in two-foot courses with one-inch joints. The joints were afterwards raked out to a depth of 1½ inches and pointed with mortar of 2 parts sand and 1 part cement. All stretchers were required to be not less than 3 feet long and not more than 7 feet.

It was specified that one-fourth of the face area should be headers from 4 to 6 feet long and not less than 2 feet in width. (Plate 22.)

The stones of the downstream face, though not dressed, were large and well proportioned and laid in courses about 2 feet thick. From the base to elevation 190 the stones of the downstream face form a series of steps, above this elevation the face conforms closely to the adopted cross-section. (Plate 24.)

The interior portion of the dam was formed of large stones, well laid in mortar, and so laid as to bond in all directions. Especial care was taken to prevent possible leakage by obtaining good bond and irregular joints. (Plate 20.)

The care and wisdom displayed in this construction is well attested by the absence of all leakage. A few slight temperature cracks have developed which open and close with the seasons, but so small and insignificant are they that they have no interest other than to appear as expected. A slight indication of moisture along one such line at times is the only indication of leakage. The dam can be described as absolutely water tight with the water in the lake at elevation 213, or one foot running over the spillway.

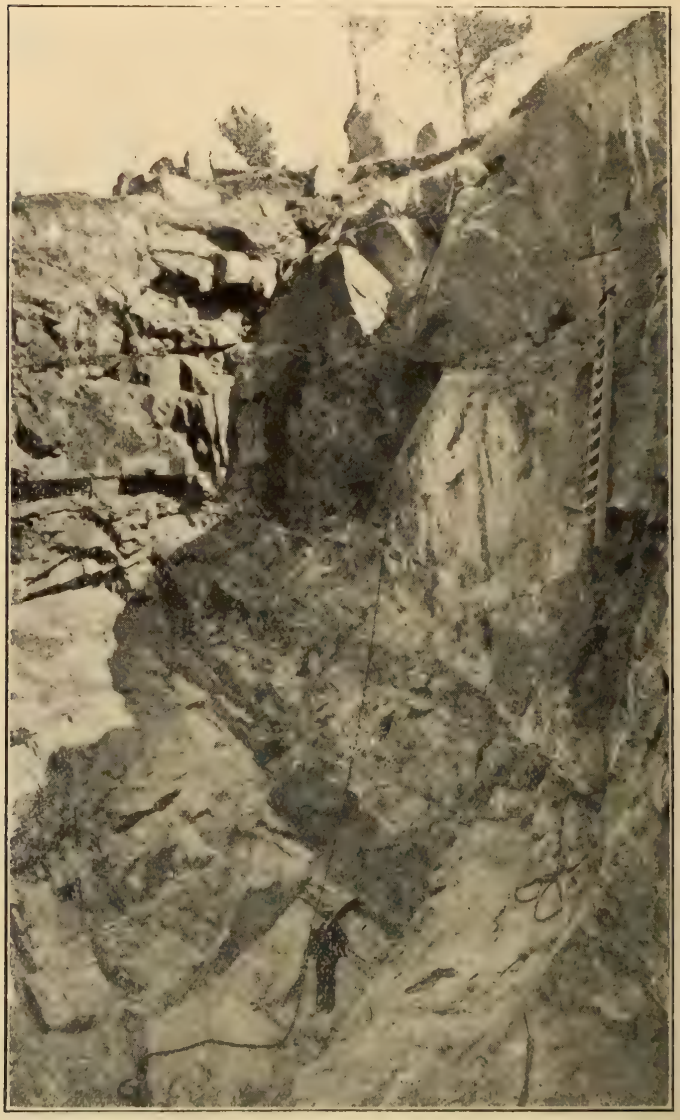


Plate 17. View Looking South, Showing Character of upper Stratification of Rock Foundation.

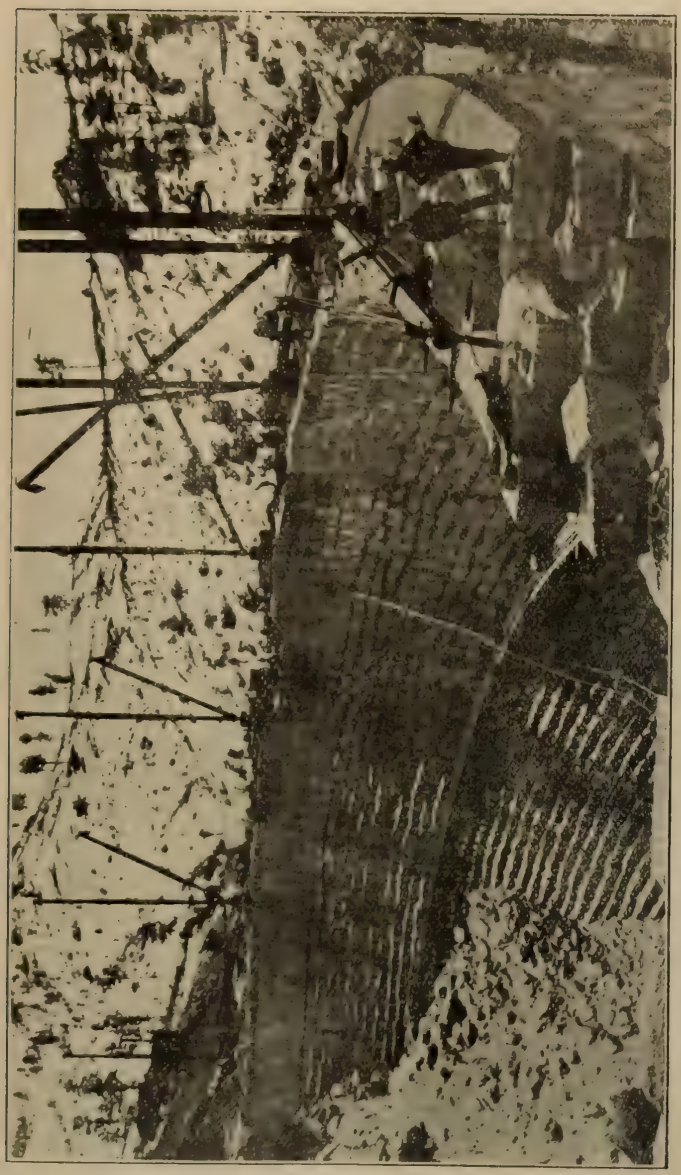


PLATE 20. VIEW OF DOWN-STREAM FACE OF DAM, SHOWING TRACK AND CARS UPON WHICH STONE WAS BROUGHT TO DAM.

PLATE 22. VIEW SHOWING CHARACTER OF STONE IN UPSTREAM FACE OF DAM.

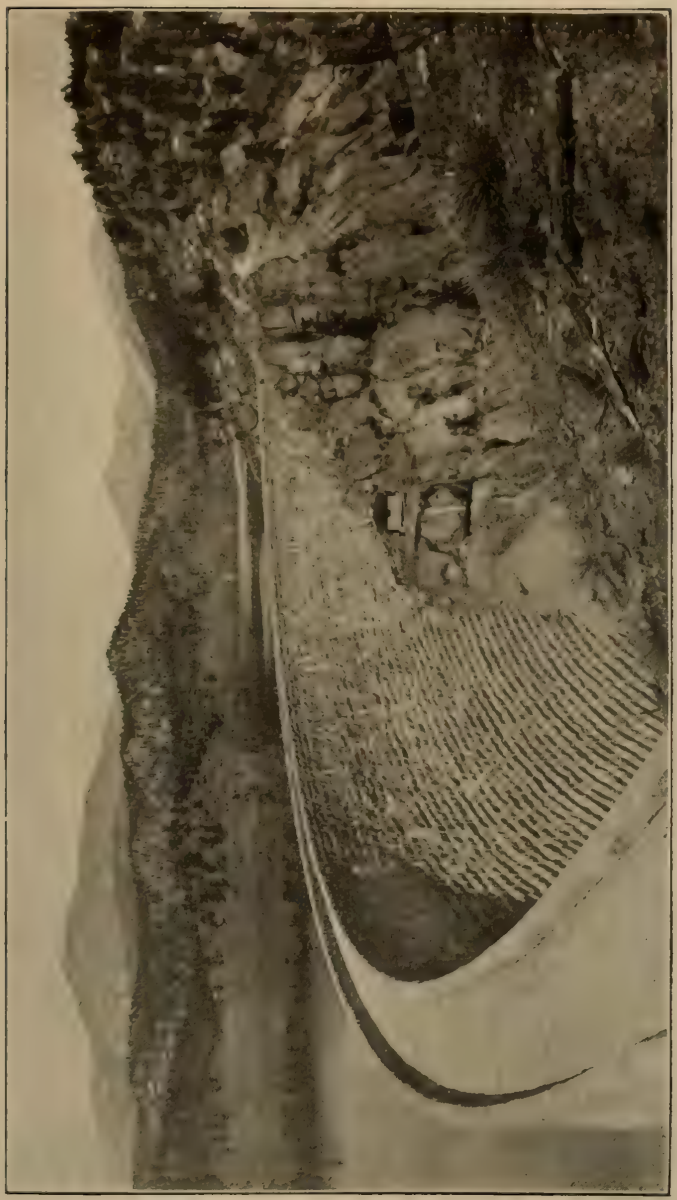


PLATE 24. VIEW LOOKING NORTH, SHOWING DOWN-STREAM FACE OF DAM.

With the exception of 6,000 barrels, Iola cement was used throughout the construction of the dam and spillway. The cement was received and tested in Denver by the Water Company and then forwarded to Cheesman, where it was stored and delivered to the contractor as required. About 83,000 barrels of cement were used in the construction of the dam and spillway.

The sand used was obtained near the lake front and about one mile from the dam. It was passed through a ⅜-inch screen and was washed so that it contained less than 1-10 of 1% of volatile and organic matter and about 31% of voids.

In the upstream face of the dam and in the bottom and at the sides where the masonry was founded in the native rock the mortar was made of two parts by volume of sand to one of cement, elsewhere the mortar was of two and one-half parts of sand to one of cement. All mortar was mixed by machinery.

The elevation of the top of the dam is 217. This is paved with 6 inches of concrete and surfaced to serve as a roadway 14 feet in width. Parapet walls 2 feet thick and 4 feet high are built on both faces of the dam. (Plate 24.)

The spillway is built upon a natural depression of a hill, and is located to the north of the dam proper. It is built to elevation 212, or 5 feet below the top of the dam. Its length is 400 feet, including slopes of 50 feet on either end. Its cross-section is shown by Plate 34, and was well founded into the native rock. (Plate 36.)

The spillway was designed and constructed by Mr. Alexander E. Kastl, of The Denver Union Water Company. Mr. Kastl also constructed that portion of the dam above elevation 210.

Water is drawn from the lake through the dam at three levels—15, 60 and 104.7.

The location of the tunnels and regulating valves is shown by Plate 14.

At the inlet of the lower water tunnel is placed a balanced valve, shown upon Plate 38. This valve is 21 feet 9 inches in length. It consists of four valve cylinders each 3 feet 4 inches long, spaced 1 foot 9 inches apart. The valves are 35 inches in diameter and have a play of 10 inches. The valves are con-

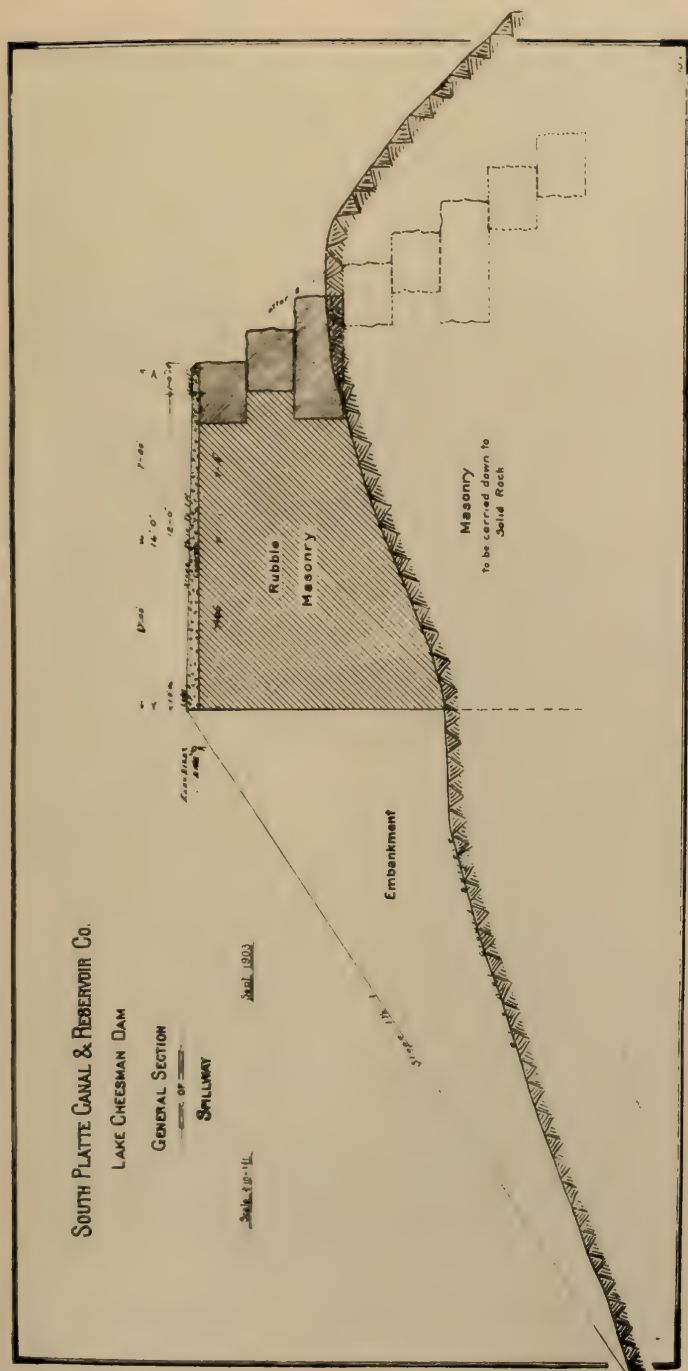


Plate 34. Cross-Section of Spillway.

Plate 36. View of Completed Spillway Looking South.

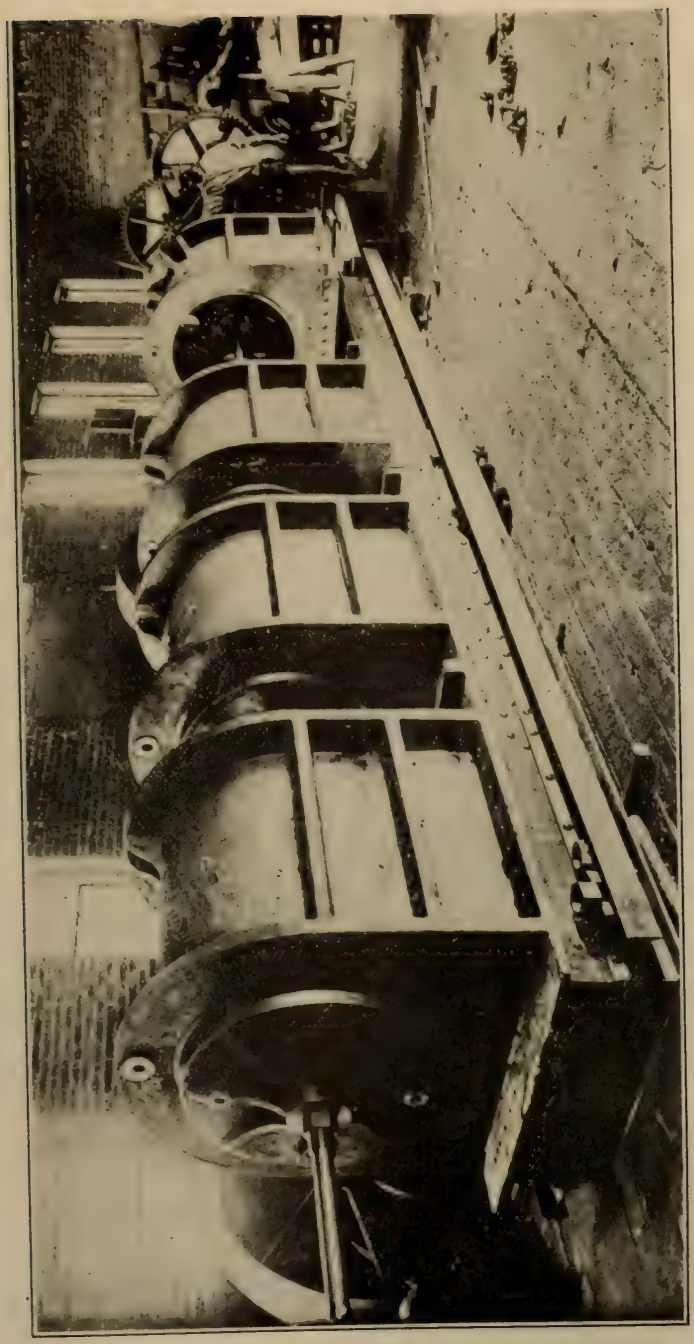


PLATE 38. VIEW OF BALANCED VALVE.

Plate 42. View Looking East, Showing Balanced Valve in Place and Completed Grating, also Inlet Portal of Second Water Tunnel, Elevation 60.

nected to a continuous shaft to which is attached a 15-inch piston contained in a cylinder 2 feet 1 inch long and spaced 13¾ inches from the end valve cylinder. This piston is actuated by water pressure admitted into either end of the cylinder in usual manner. Pressure pipes for this purpose are carried under the water tunnel to the outlet portal. All wearing surfaces about the valve are of brass.

In placing the balanced valve it was inclined about 20° 30′ from the horizontal, the hydraulic cylinder being at the upper end. (Plate 42.)

A grating was placed about the valve consisting of 2″x⅝″ bars, spaced 2⅜″ apart, attached to and supported by 6″ I-beams.

The lowest level to which water in the lake can be drained is plus 15.

The design in placing of this balanced valve and twin valve and the excavation of the water tunnels was the work of Mr. C. P. Allen, formerly chief engineer of The Denver Union Water Company, who was succeeded by Mr. C. L. Harrison.

By referring again to Plate 14, it will be noted that a valve is placed in the lower tunnel immediately in front of the junction of the inclined tunnel. This valve is of the twin type and the method of placing and securing the same is shown by Plate 43. This twin valve is made up of two valves placed end to end, of the usual double gate type with hydraulic lift cylinders. Double gate valves operated by water power are placed in the upper and middle tunnels, as shown by Plate 14.

Immediately below the junction of the upper and middle tunnels, a Tainter gate is placed in the inclined tunnel. The arrangement and method of placing this valve is shown by Plate 47. It is operated, as shown, by means of gearing placed in a shaft 31′3″ above the center or pivotal point of the valve. Thus far the action of this valve has been very satisfactory under all heads.

All of these valves are operated in chambers which are about 15 feet square. Access to these chambers is by a manway tunnel excavated in the granite and having a cross-section of about 5′x8′, which is indicated both in plan and cross-section by dotted lines on Plate 14. Its upper entrance is through a

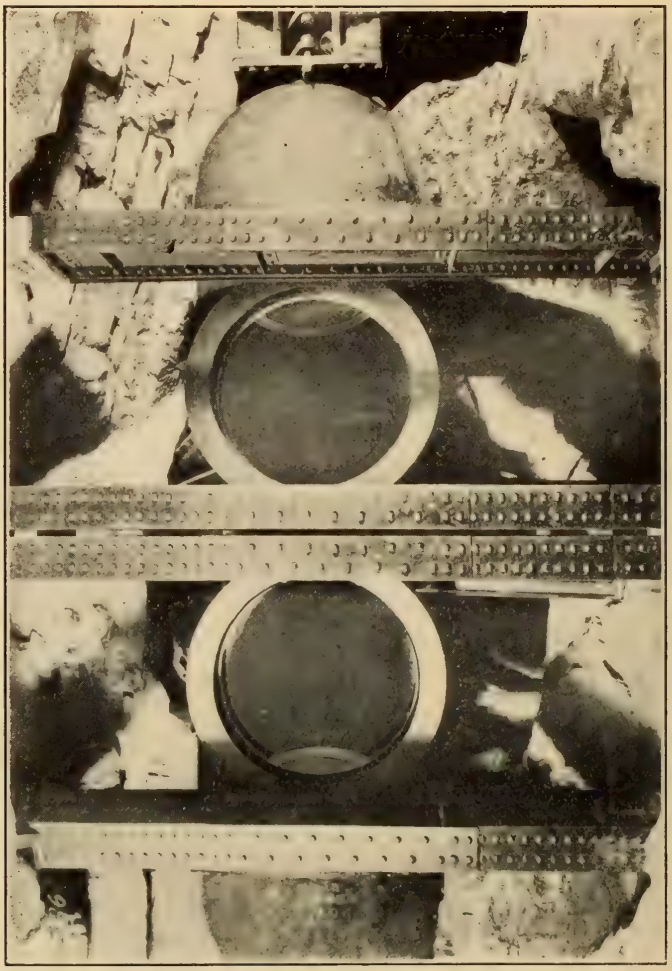


Plate 43. View Looking Upstream in Water Tunnel, Showing Method of Supporting Twin Valves.

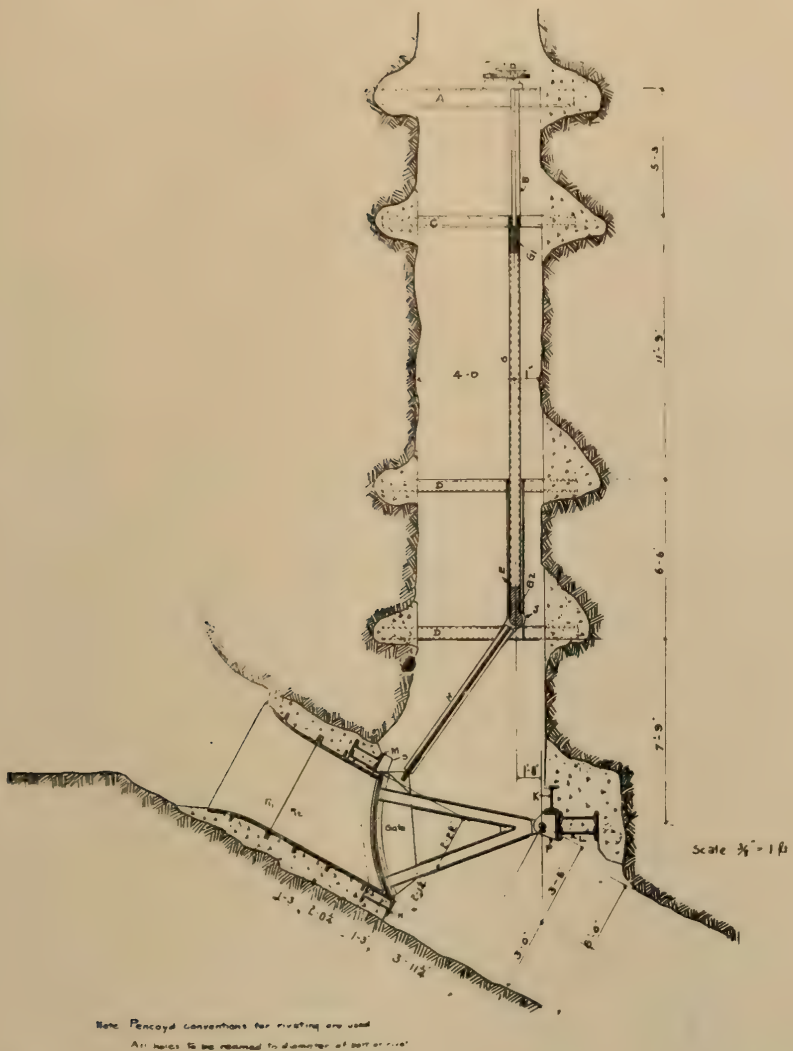


Plate 47. View Showing Arrangement and Placing of Tainter Gate.

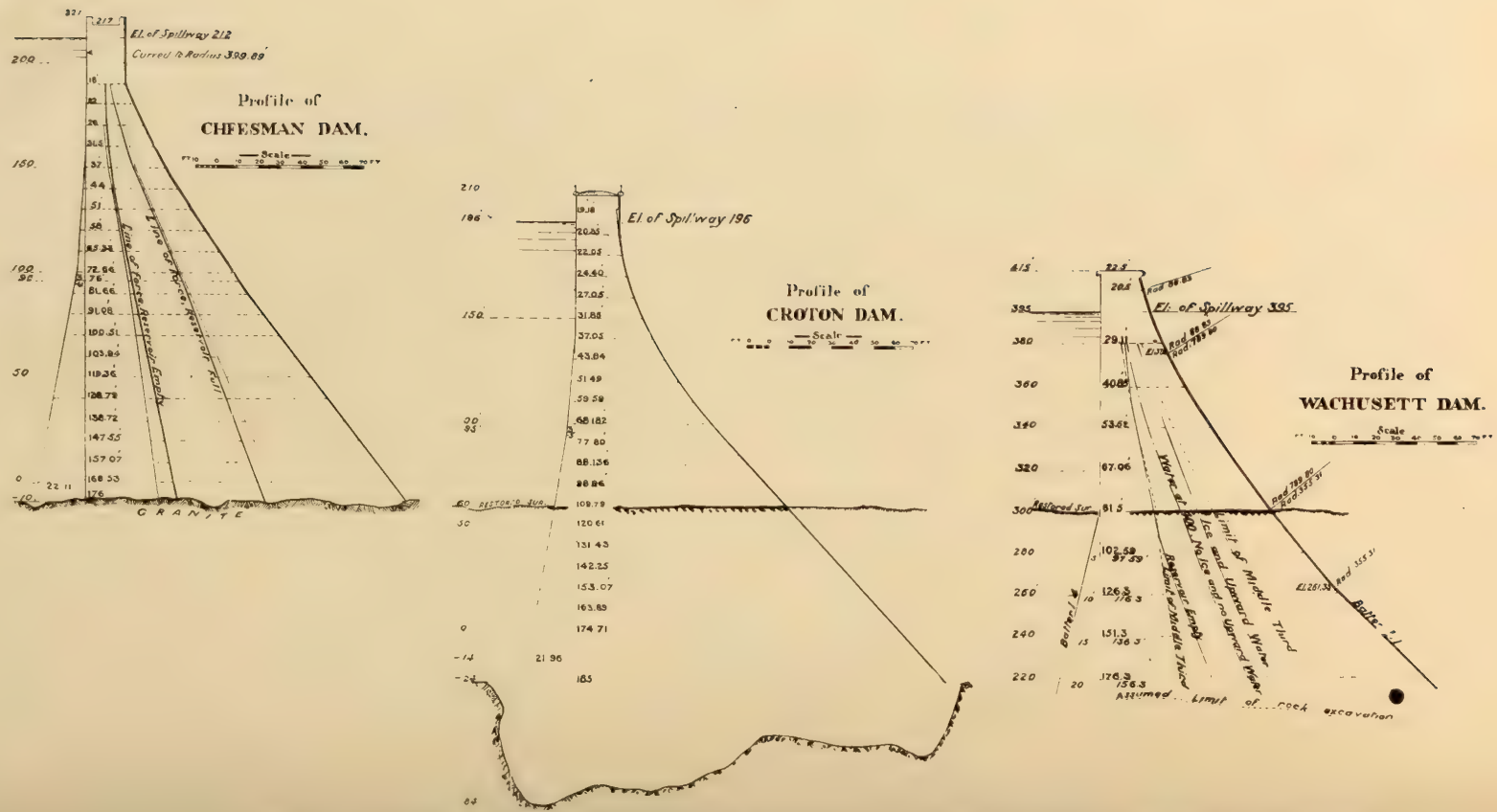


Plate 48. Cross-Sections of Cheesman Dam, Croton Dam, and Wachusett Dam, Referred to a Common Level for Spillways.

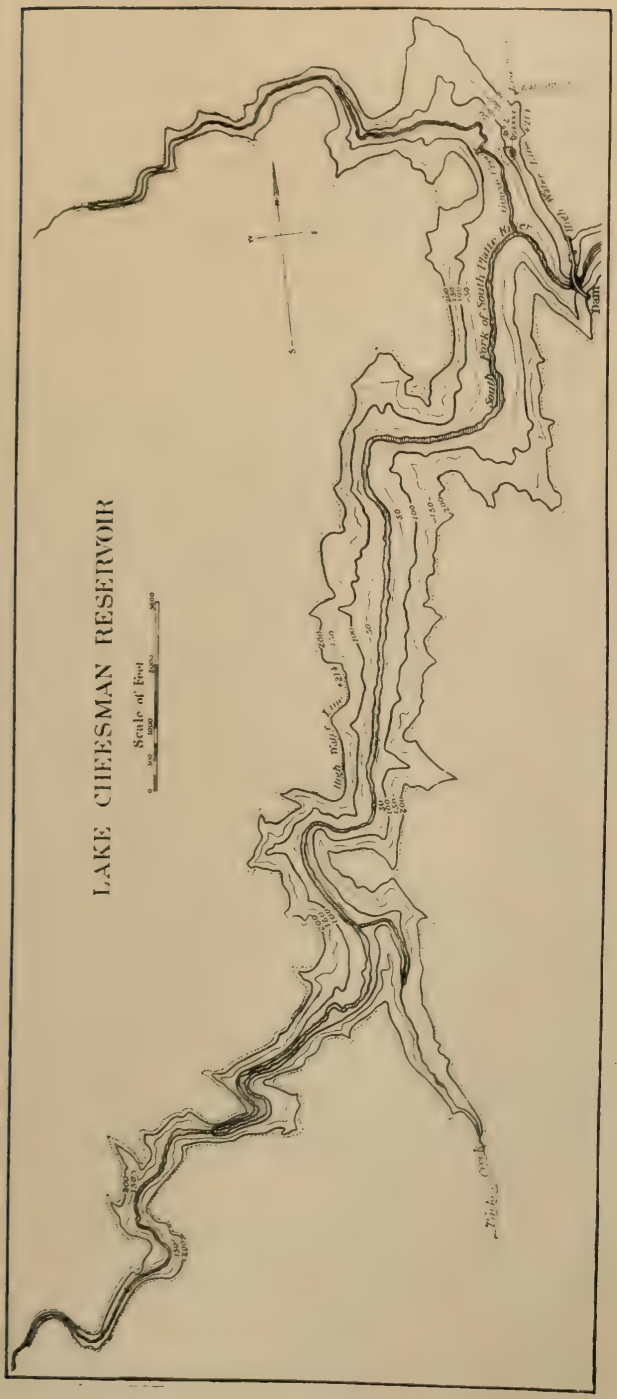


Plate 50. Plan of Lake Cheesman.

masonry building, shown to the rear of the dam on Plate 24. It has a lower entrance at the level of the bottom of the gorge, as shown in the plan by Plate 14. This manway tunnel is easily traversed by means of concrete steps of easy assent.

An electric generator directly connected to a Pelton wheel, located in one of the valve chambers, gives light throughout the tunnel and chambers, as well as arc and incandescent lights about the dam, lake front, and the Company's buildings located at the north end of the lake about 4,000 feet from the dam.

A second Pelton wheel directly connected to a triplex pump is located in the same valve chamber as the electric generator and furnishes hydraulic power through piping to the several valve chambers for the operation of the valves. In addition to this power, hand power pumps are connected to the hydraulic cylinder of each valve, by which the valves can be operated.

It may be of interest to exhibit a drawing which has been prepared to show the comparative depths of storage of Cheesman Dam, the New Croton Dam and the Wachusett Dam. (Plate 48.) The cross-sections of these three dams are here shown drawn to the same scale and having their river beds at a common level.

The purpose for which Cheesman Dam has been constructed is to impound water for the protection and insurance of an ample and abundant supply of water for the City of Denver. That the construction of the dam has accomplished this is without question.

The necessity of thus impounding water for a reserve supply is apparent to one who is informed of the climatic conditions in Colorado and the limitations covering water rights.

The average yearly precipitation for the past 34 years in Denver amounts to 13.99 inches.

Records have been kept at Lake Cheesman since 1900 of the amounts of water flowing in the South Fork of the South Platte River, including that from Goose Creek. These amounts are compiled in the following table, the flows being in million gallons.

TABLE GIVING AMOUNT OF FLOW IN MILLION GALLONS IN SOUTH FORK OF SOUTH PLATTE RIVER AT CHEESMAN DAM

	JAN.	FEB.	MAR.	APL.	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1900	523	489	1605	4603	17784	25[illegible]	[illegible]73	1706	1525	1691	1319	604	[illegible]897
1901	291	272	1346	3343	6635	5041	1046	6645	3224	1590	2013	1754	[illegible]782
1902	1217	342	814	1935	763	289	102	20[illegible]	117	246	301	279	[illegible]
1903	171	70	965	2022	873	6709	2387	1437	1459	688	1154	293	18208
1904	70	119	663	1220	3324	7211	2604	5325	2976	2511	1324	466	28627
1905	212	333	2193	4943	9293	8041	1490	2920	2661	1356	1390	320	[illegible]
AVERAGE	414	271	1338	3141	6612	8435	2136	3093	1959	1480	1255	529	31015

Plate 49. Table Giving Amount of Run-Off in South Fork of South Platte River During the Years 1900, 1901, 1902, 1903, 1904 and 1905, Measured at Lake Cheesman.

During the irrigation season, which extends from April 1st to November 1st, the laws of the State forbid the storage of water, and the right to take the water from the streams during that season is granted by the State under duly certified filings. As the water of the South Platte River is over appropriated, it is apparent how essential it is that adequate storage capacity be provided for the non-irrigation season to guard against a possible exceptionally long season of drought.

Lake Cheesman has a storage capacity at the spillway level and above elevation 15 of nearly 30,000,000,000 gallons of water, and this body of water is held as a reserve supply and is drawn upon only in rare intervals, as the Company has other and abundant sources of supply for constant use.

It is located and surrounded by a vast area of territory controlled by the Federal Government and set apart as a timber reserve, embracing 1,822,000 acres.

By special act of Congress, The Denver Union Water Company owns in fee simple about 10,000 acres immediately surrounding Lake Cheesman, which tract is enclosed by a six-strand wire fence, thus affording an additional factor against possible pollution of the lake.

Lake Cheesman flows over a territory of 875 acres, as shown by Plate 50. Measured from its headquarters in the South Platte and Goose Creek, it is a body of water about 7 miles in extent.

All trees and vegetable growth upon the reservoir site below elevation 214 were cut and burned.

Nestled in the heart of the Rocky Mountains, in a semi-arid district, it is a beautiful testimony to the spirit and enterprise

Plate 51. W. S. Cheesman, President of The Denver Union Water Co

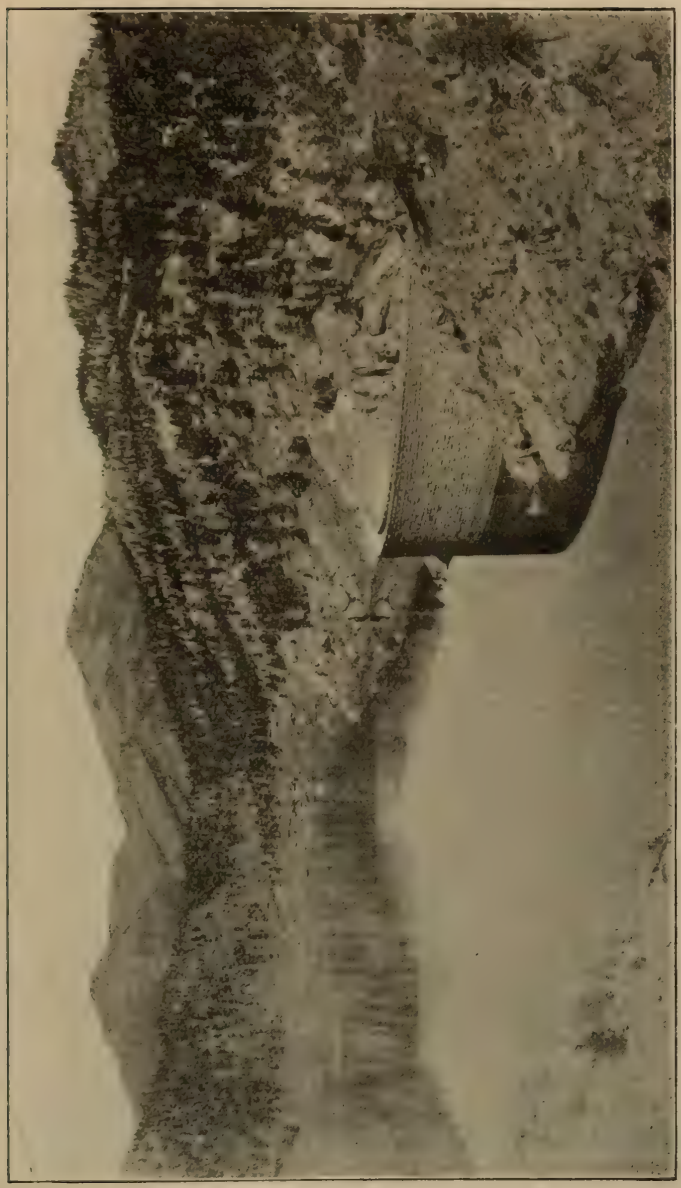


PLATE 53. VIEW LOOKING NORTH, SHOWING NORTHERN END OF LAKE AND CHEESMAN DAM.

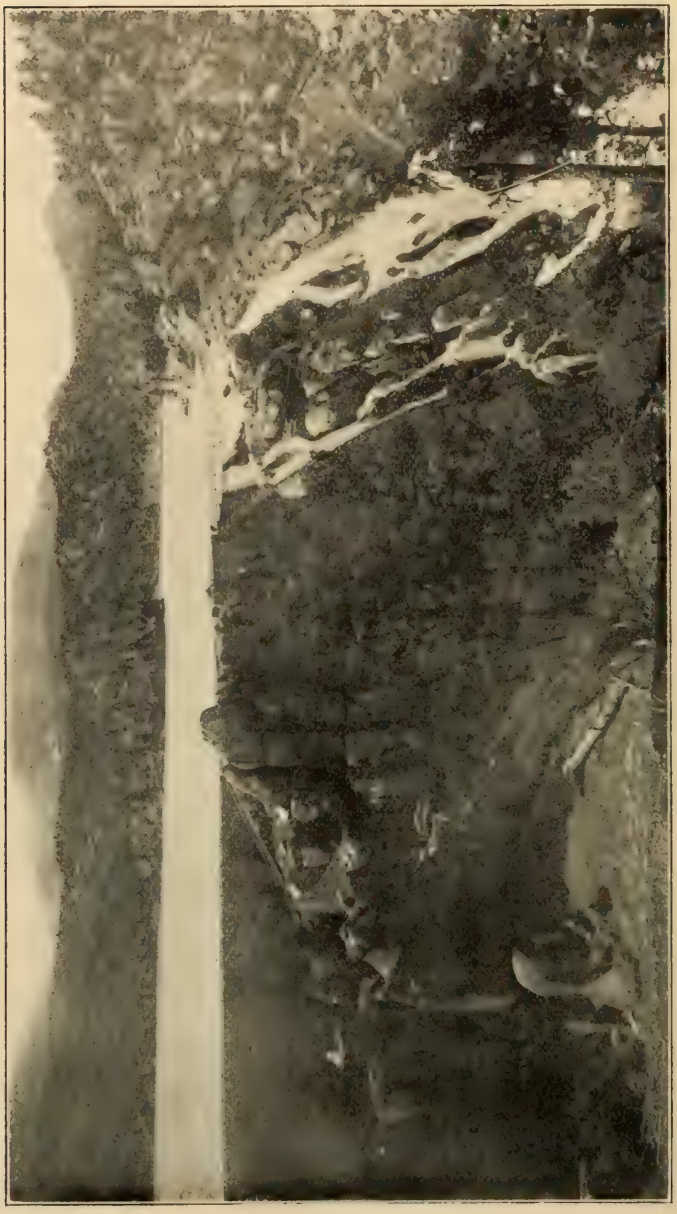


PLATE 54. VIEW LOOKING NORTHWEST, SHOWING NORTHERN END OF LAKE AND WATER FLOWING OVER SPILLWAY.

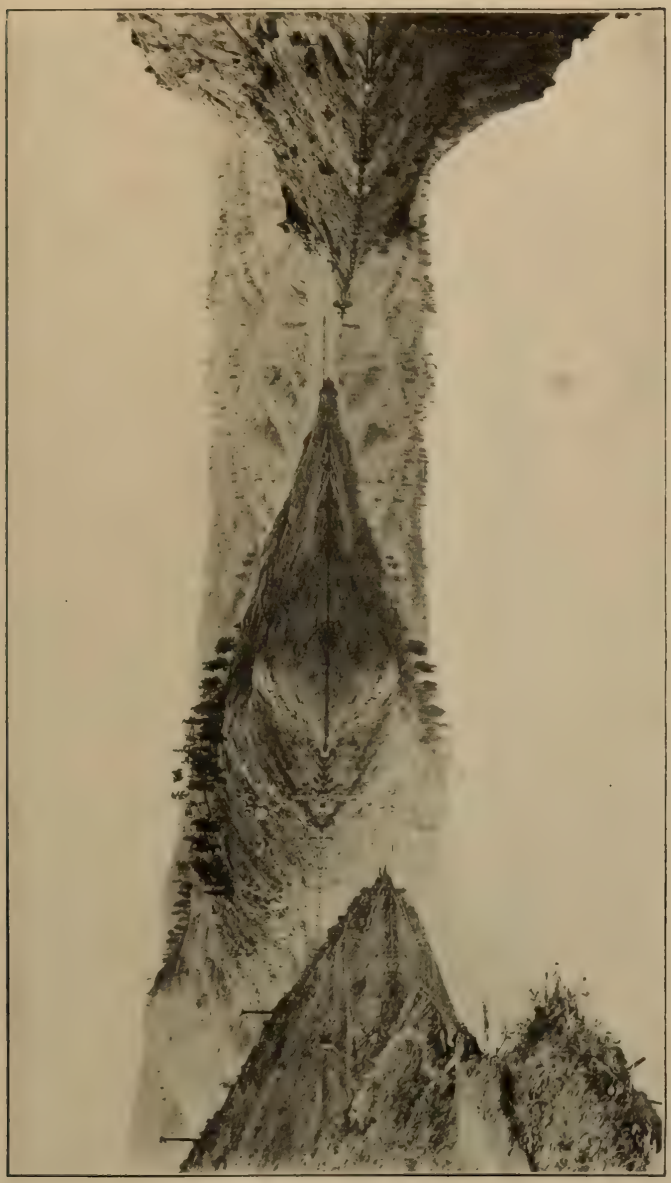


Plate 57. View of Lake Cheesman, Looking Southwest, Showing Promontory Opposite Dam.

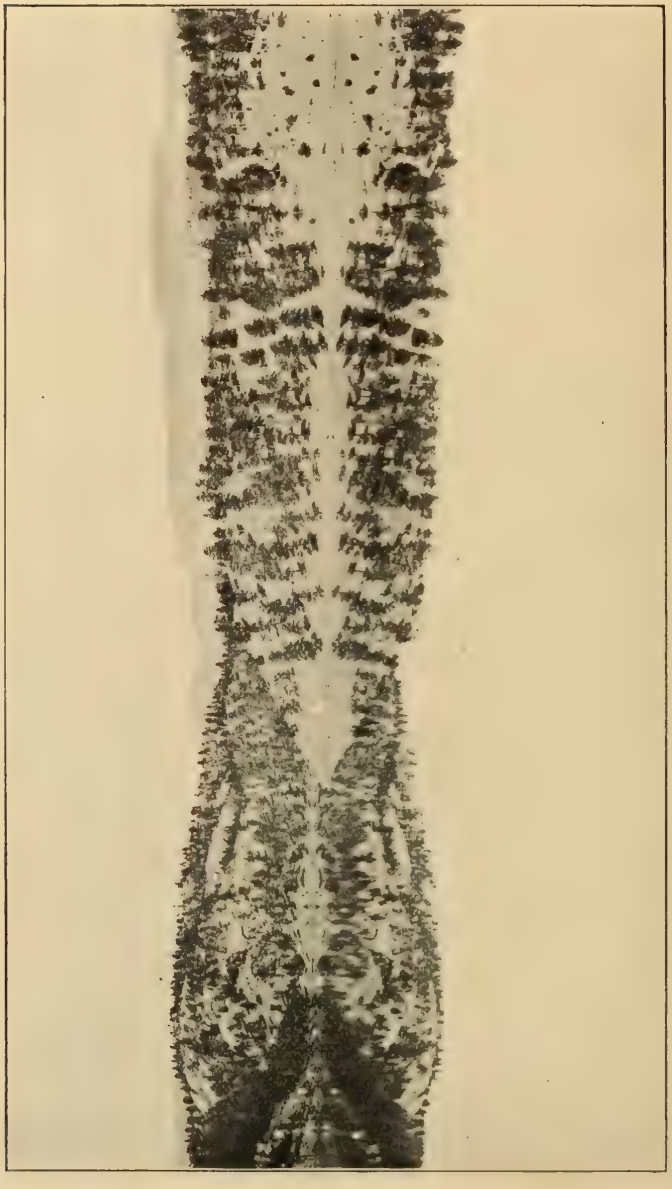


Plate 59. View Looking West Across Lake Cheesman at the Present Mouth of Goose Creek, Showing Remarkable Reflection in the Water of the Lake.

of those who have placed it there to serve as a bulwark and guardian over one of the greatest needs of a great and growing city.

The man above all to whom praise should be rendered for the consummation of this great enterprise is Mr. Walter S. Cheesman, President of The Denver Union Water Company, a photograph of whom is here given.

He it was who first conceived the necessity and advantages attaching to the storage of this vast volume of water, and through his indefatigable labors, born of a spirit of broad-mindedness and loyalty to the city which he has largely helped to build, he has reared a monument to himself which will be an enduring blessing not alone to the generation which he has so faithfully served, but to the future generations who will perhaps better appreciate the devotion and effort of the man who has made all this a reality.

I can not forego the pleasure of showing you a few scenes that are to be found upon this beautiful sheet of water amid its setting among those grand mountains. While not of an engineering interest a few of these views may serve as a pleasant after-touch to an otherwise prosaic paper. (Plates 53, 54 and 57.)

I desire to show you Plate 59, which indicates the wonderfully beautiful reflections which are due to the extraordinary clearness of the water and air.

Discussion

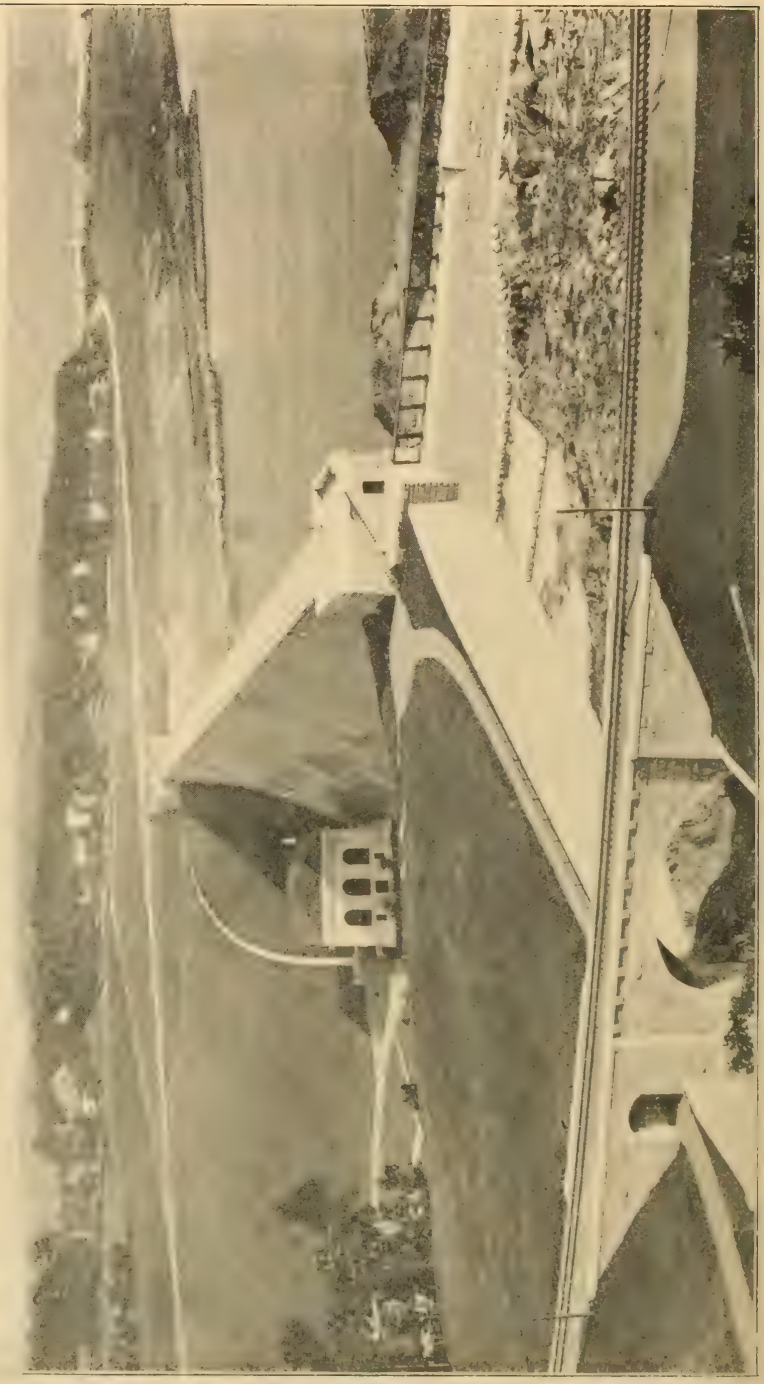
Mr. William R. Hill (by letter): The American Water Works Association should be congratulated for having in its transactions so complete a description of the Cheesman Dam as is given in the paper presented by Mr. George T. Prince. That dam has a height sufficient to store the unprecedented depth of 212 feet of artificially impounded water, but this depth will soon be surpassed by both the Shoshone and Roosevelt Dams, now in the course of construction, which will have effective heights of 233 and 220 feet, respectively.

While the paper fully describes the engineering and interesting features of the dam, still by the construction of that structure and of others by the Denver Union Water Company, there is presented a most important lesson for the discussion, now attracting wide consideration, that is, the superior advantages derived by the public from a private or a municipal ownership of a water supply. The speaker is not desirous of raising a discussion or even expressing his own views upon this subject, still he begs to be permitted to say that he has no hesitation in stating that the people of Denver, supplied by a private company, are enjoying advantages that are denied to many others supplied by either a municipal or a private plant. In concurrence with this the people of that city can justly challenge any city in the world for a comparison of the quality and quantity of water furnished and stored for use. Every drop of their excellent mountain stream water is filtered and the aggregate storage capacity of their artificial reservoirs is sufficient to supply the city for a period of about three years, even though not a drop of water entered their reservoirs during that tme. Hence, the question of contamination or dearth of supply is entirely effaced and this condition has been made possible only by costly construction. In considering the above we should not be unmindful of the fact that the consumption of water in Denver is now over 200 gallons per capita per day or about double the quantity regarded as a sufficient supply under ordinary conditions.

While the quality and quantity are the most important features to be considered, still the people of that city are enjoying all the other advantages derived from an excellent

system of water works. The distributing system is well extended through the city, affording good protection against fire. At reasonable rates they are furnished a bountiful supply for all necessary purposes and such a supply means more to that city than might be anticipated even by a water works official. Denver is a handsome city, with fine parks and beautiful homes of stone, brick or cement construction, surrounded by green and velvety lawns, of which the people are justly proud. The beautiful parks and lawns are made possible only by the bountiful supply of water, as they could not exist if depending upon rain for nourishment, as the rainfall at Denver is very light, being only about 14 inches per annum or about one-third of the amount falling in the New England States, and in many months they scarcely have a trace of rainfall. In considering this we should not be unmindful of the fact that vegetation in that territory requires a great quantity of water because of the light character of the soil. Thus it can be seen that a large quantity of water is required for irrigation to beautify the city and the value of a bountiful supply is made apparent.

The perfection of the water works, the most important requisite of the city, is due to the openhearted and farsighted character of Mr. Walter S. Cheesman, President of the Denver Union Water Company, who looked almost with disdain to obstacles in perfecting their great plant. He has established in that city the best possible water system, and both he and the citizens are to be congratulated.



WACHUSETT DAM, SHOWING RAILROAD BRIDGE OVER WASTE CHANNEL.

METROPOLITAN WATER WORKS.

By Dexter Brackett.

In the year 1892 the City of Boston had nearly reached the capacity of its sources of water supply, and there were several other metropolitan municipalities whose sources of supply were either inadequate in quantity or inferior in quality. It was evident that for the future supply of the Boston Metropolitan District a comprehensive scheme was demanded, and as such a scheme must necessarily affect not only the different municipalities to be supplied but also the towns in the more remote districts from which the water would be obtained, it appeared advisable to have the investigation of the question made under the supervision of the State.

In 1893 a bill providing for the appointment of a commission to investigate the question was introduced in the Legislature by one of the representatives of the City of Boston, which resulted in the passage of an Act approved June 9, 1893, directing the State Board of Health to investigate the subject and report on or before the first Wednesday in January, in the year 1895.

After a very careful and thorough investigation of the possible sources of supply, the more important of which were Lake Winnipiseogee, in New Hampshire, the Merrimack River and the South Branch of the Nashua River, the State Board of Health, in February, 1895, presented its report recommending the taking of the water of the South Branch of the Nashua River at a point above the Lancaster Mills in the town of Clinton, and the construction of works for utilizing this source in conjunction with the sources then used by the City of Boston.

The Metropolitan Water Act, Chapter 488 of the Acts of the year 1895, approved June 5, 1895, provided that the Governor should appoint three water commissioners who should constitute the Metropolitan Water Board, and that this Board should construct, maintain and operate a system of water

works substantially as recommended by the State Board of Health.

The Board was thus directed by the Act to take for the Metropolitan Water Works the waters of the South Branch of the Nashua River, at a point in the town of Clinton within the Commonwealth and about 35 miles westward from Boston; to construct for the storage of the waters a dam and reservoir; to build an aqueduct from the dam at Clinton, about 12 miles long, to the Sudbury Reservoir situated in the town of Southborough and the city of Marlborough, which had already been begun by the City of Boston; to complete this reservoir and connect it with the Sudbury Aqueduct of the City of Boston; to take from the City of Boston the Cochituate, Sudbury and Mystic systems, which were its sources of water supply, and the Chestnut Hill Reservoir and pumping station; also to take Spot Pond, which was then used as a source of water supply by the cities of Malden and Medford and the town of Melrose; and to lay the main pipes required to supply at some proper point each of the several cities and towns embraced within the water district.

The Board was given broad powers, not only for the construction of the works, but also for the taking of property, for the changing of highways and railroads, and for the conduct of such operations as should be deemed necessary for protecting and preserving the purity of the water.

No estimate of the total expenditure involved in the scheme adopted was made, but it was provided that the Commonwealth should issue bonds to an amount not exceeding $27,000,000, the proceeds of which should be applied to meet the expenditures occasioned by the various operations of the Board. For the payment of the loan at its maturity a sinking fund was to be established, and assessments were required to be made upon the various municipalities included within the district sufficient to meet the cost of maintenance and the interest on the indebtedness, and for contributions to a sinking fund sufficient to secure the payment of the indebtedness at its maturity. Provision was made by the Act not only for the payment for all lands and other property taken for the works, and for the loss of water and water power occasioned by the diversion of

the waters of the river, but also for the payment of indirect damages occasioned by the depreciation of the property affected by the operations of the Board, but which was not taken. Annual payments were directed to be made to the towns of Boylston and West Boylston, in which the larger part of the lands were taken for the new reservoir, to compensate them for the loss of taxes and other damages suffered by them in their corporate capacity; and compensation was afforded to individuals for injury occasioned to established business and on account of the loss of employment.

The Metropolitan Water District, as established under the Act, consisted of the cities of Boston, Chelsea, Everett, Malden, Medford, Newton, Somerville and the towns of Belmont, Hyde Park, Melrose, Revere, Watertown and Winthrop. The Act further provided that any one of the other cities and towns, any part of which is within a radius of ten miles of the State House, should, on application, be admitted into the District, upon payment of such sum of money as should be determined by the Board. Under this provision the city of Quincy and the towns of Nahant, Arlington, Stoneham, Lexington and Milton have since been admitted into the District, and under authority given by the original and subsequent acts, water is also supplied to the town of Swampscott and to a small portion of the town of Saugus, both of which are without the limits of the District.

The nineteen municipalities within the District as now established had, in 1905, a population, according to the census of that year, of 946,300, as appears by the following table:

City or Town.	Population, Census of 1905.
Boston	595,330
Somerville	69,272
Malden	38,037
Chelsea	37,289
Newton	36,827
Everett	29,111
Quincy	28,076
Medford	19,686
Hyde Park	14,510
Melrose	14,295
Revere	12,659
Watertown	11,258
Arlington	9,668
Milton	7,054
Winthrop	7,034
Stoneham	6,332
Lexington	4,530
Belmont	4,360
Nahant	922
Total population of Metropolitan Water District	946,300
Swampscott	5,141
Part of Saugus	200

Water is supplied to Swampscott and a small portion of the town of Saugus outside the limits of the Metropolitan Water District. The city of Newton and the town of Hyde Park are supplied from local sources, so that the population supplied from the Metropolitan Works in 1905 was 902,090.

The Metropolitan Water Board, as first constituted, consisted of Henry H. Sprague of Boston, chairman; Wilmot R. Evans of Everett, and John R. Freeman of Winchester. Mr. Freeman, on account of removal from the Commonwealth, resigned his membership on April 15, 1896, and Henry P. Walcott, M. D., of Cambridge, the chairman of the State Board of

Health, was appointed in his stead and began service upon the Board on April 16, 1896. On March 20, 1901, the Metropolitan Water Board and the Board of Metropolitan Sewerage Commissioners were abolished and a new Board, known as the Metropolitan Water and Sewerage Board, was created and given all the powers and duties of the abolished Boards. This Board, composed of Henry H. Sprague and Henry P. Walcott from the Metropolitan Water Board, and James A. Bailey, Jr., who had been the chairman of the Sewerage Commission, has remained unchanged in membership. William N. Davenport has been secretary of the Board since its organization. Frederic P. Stearns, as chief engineer of the State Board of Health, had charge of the investigations made in 1893 and 1894 previous to the passage of the Act, and as chief engineer of the Water Board and of the Water and Sewerage Board he has had charge of both the designing and construction of all the water works built since 1895.

In order to obtain, as quickly as possible, an addition to the water supply, the first work undertaken was the building of an aqueduct for conveying water from the Nashua River to the Sudbury Reservoir, the completion of this reservoir which had been commenced by the City of Boston, the increase of pumping facilities, and the laying of main pipes from the Chestnut Hill pumping station to connect with Spot Pond and the various cities and towns to be supplied with water.

The first contract entered into by the Board, which was for cast-iron pipes, was made December 27, 1895. The first contract for the Wachusett Aqueduct was made February 14, 1896, and on March 7, 1898, the aqueduct was substantially completed, and water from the Nashua River was diverted through the aqueduct into the Sudbury Reservoir, which, although not finished until December, 1898, was at that time so far completed as to be used to a limited extent.

On January 1, 1898, formal possession was taken of the works of the City of Boston, and the use of water from the Mystic supply, from which, up to that time, about 12,500,000 gallons per day had been supplied to Somerville, Chelsea, Everett and portions of Boston, was discontinued. On December 11, 1898, a new 30-million gallon pumping engine was first operated at the high-service station at Chestnut Hill.

During the year 1899 the Fells Reservoir, used for the supply of the higher portions of the northern part of the District, was completed and placed in service, and the work of improving Spot Pond was commenced. During the year 1900 the low-service pumping station at Chestnut Hill and the high-service pumping station at Spot Pond were completed and the pumping engines placed in service. The work of raising and improving Spot Pond was also completed during that year.

The first contract for the removal of soil from the Wachusett Reservoir was made July 14, 1897, and work on the final contract was completed in November, 1905. In 1897 a temporary dam was constructed across the Nashua River preliminary to the construction of the main dam, also for the purpose of diverting the water of the river into the Wachusett Aqueduct. The work of excavating for the main dam was commenced in July, 1900, by day labor. The contract for the dam was made October 1, 1900, and the dam was practically completed at the end of 1905. The construction of the Weston Aqueduct was begun May 22, 1901, and the aqueduct was completed and placed in service December 29, 1903.

Description of Works.

Water supplied by the Metropolitan Water Works is obtained from three sources, Lake Cochituate, the Sudbury River and the Nashua River. Lake Cochituate and the Sudbury River were acquired as sources of water supply by the City of Boston, the former in 1846 and the latter in 1872, and works for storing and conveying the water from these two sources were constructed by the City of Boston.

The construction of works for storing and conveying the water of the Nashua River was begun by the Metropolitan Water Board in 1895, and is now practically completed. Water was first drawn from this source on March 7, 1898. The Sudbury Reservoir of the Sudbury River supply was begun by the City of Boston and completed by the Metropolitan Water Board.

The works as at present constituted comprise the

Wachusett Reservoir on the Nashua River, capacity 63,000,000,000 gallons;

Eight storage reservoirs on the Sudbury River watershed, with a combined capacity of 13,616,100,000 gallons;

Lake Cochituate, capacity 2,242,400,000 gallons;

Wachusett Aqueduct for conveying water from the Wachusett Reservoir to the Sudbury Reservoir of the Sudbury supply, capacity 300,000,000 gallons in 24 hours;

Weston Aqueduct and Reservoir for conveying water from the Sudbury Reservoir to the Metropolitan District, capacity of aqueduct 300,000,000 gallons per day;

Sudbury River aqueduct for conveying water from the reservoirs on the Sudbury River to Chestnut Hill Reservoir, capacity 103,000,000 gallons per day;

Cochituate Aqueduct for conveying water from Lake Cochituate to the Chestnut Hill Reservoir, capacity 18,000,000 gallons per day;

Chestnut Hill Reservoir, which receives and stores water supplied through the Sudbury and Cochituate aqueducts, and from which water is pumped for supplying the Metropolitan District;

Five pumping stations located at Chestnut Hill Reservoir, Spot Pond, West Roxbury and Arlington, containing 13 pumping engines having an aggregate capacity of 204,500,000 gallons in 24 hours;

Six distributing reservoirs, of which Spot Pond is the largest, and two standpipes, located in the Metropolitan District, having a combined capacity of 1,881,230,000 gallons;

84.2 miles of pipes, ranging in size from 60 inches to 12 inches in diameter, through which water is delivered to a population of about 900,000 residing in eighteen cities and towns.

Wachusett Reservoir.

The Wachusett Reservoir is located in the towns of Clinton, Boylston and West Boylston, and is formed by a dam across the South Branch of the Nashua River located about half a mile above the settled portion of of the town of Clinton, and

by two earth dikes, one on either side of the valley a short distance above the main dam.

The river above the dam has a watershed of 118.32 square miles. The reservoir is 8.41 miles long, with a maximum width of 2 miles, an area of 4,195 acres, or 6.56 square miles, and a capacity of 63,068,000,000 gallons. The maximum depth of water is 129 feet; the average depth 46 feet.

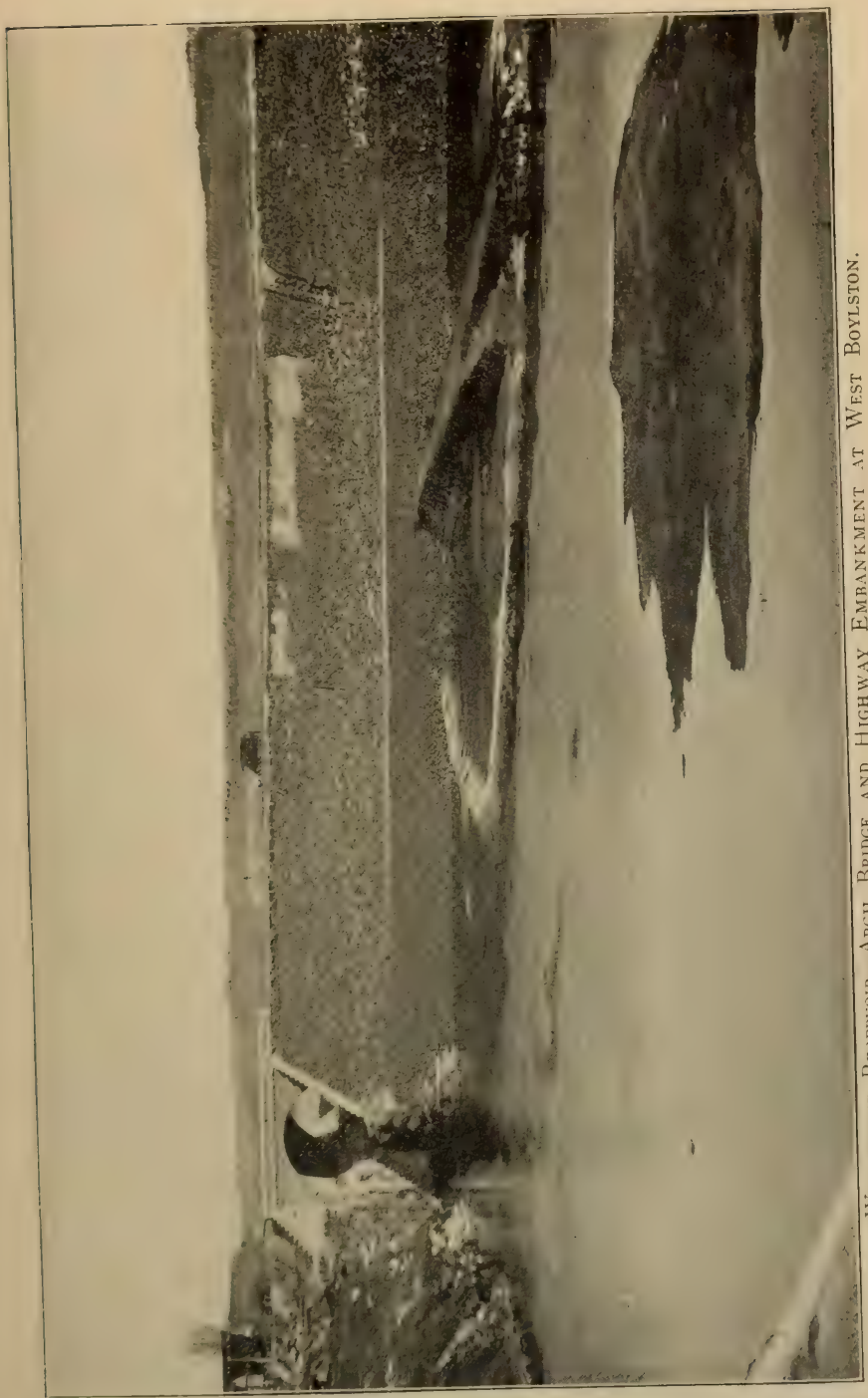
In constructing the reservoir the soil was stripped from 3,943 acres of the submerged area to an average depth of one foot, the quantity removed being 6,900,000 cubic yards, and over about 150 acres where there were deep deposits of muck, gravel was spread to a depth of one foot. The plant used by the contractor in removing the soil included 27 miles of railroad track of 3-feet gage, 25 eight- to sixteen-ton locomotives, and 725 cars of from 1¾ to 3½ cubic yards capacity. The land required for the reservoir contained 6 large mills, 8 schoolhouses, 4 churches and about 360 dwelling houses occupied by 1,700 people.

In order to provide a new location for the Central Massachusetts Railroad, which ran for 6½ miles through the reservoir site, about 4½ miles of new railroad was built, the construction including a rock tunnel 1,110 feet long, a steel viaduct 917 feet long crossing the valley of the Nashua River, with a maximum height of 133 feet, and 1,500 linear feet of rock cut having a maximum depth of 56 feet.

The construction of the reservoir necessitated the discontinuance of 19¼ miles of roads and the construction of 11.8 miles of new roads, one of which crosses the reservoir on an embankment 700 feet long and from 50 to 70 feet in height.

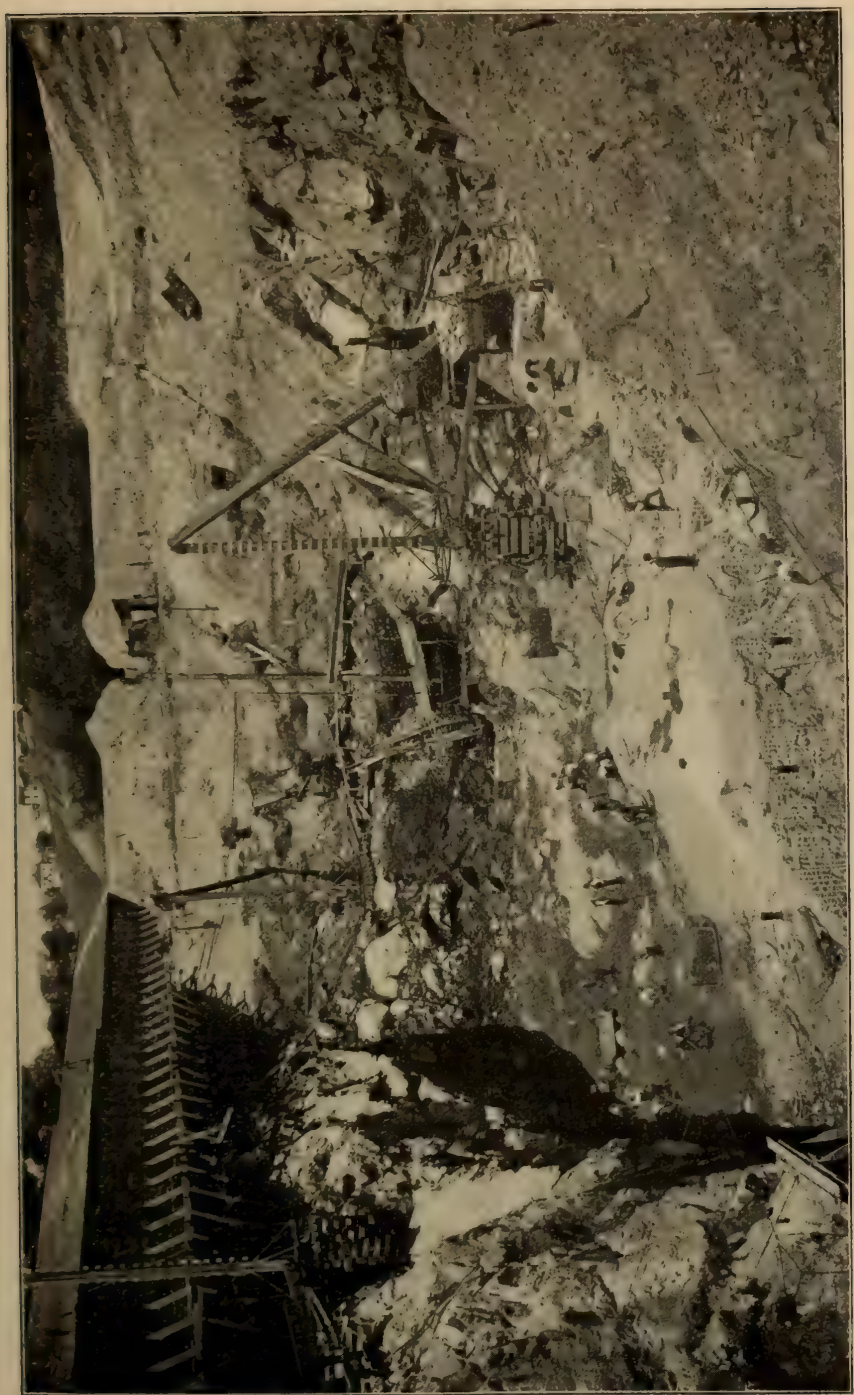
The Wachusett Dam is a granite masonry structure comprising the main dam 944 feet long, including abutments at each end, crossing the valley of the river, with its top 20 feet above high-water level in the reservoir, and a waste weir 452 feet long, over which the flood waters can be discharged into a channel 1,150 feet long excavated in rock following the contour of the hillside to the river channel below the dam.

The main dam is composed of granite rubble masonry quarried about a mile from the dam, with facing, where exposed, of ashlar quarried in Chelmsford, Mass. The height of the

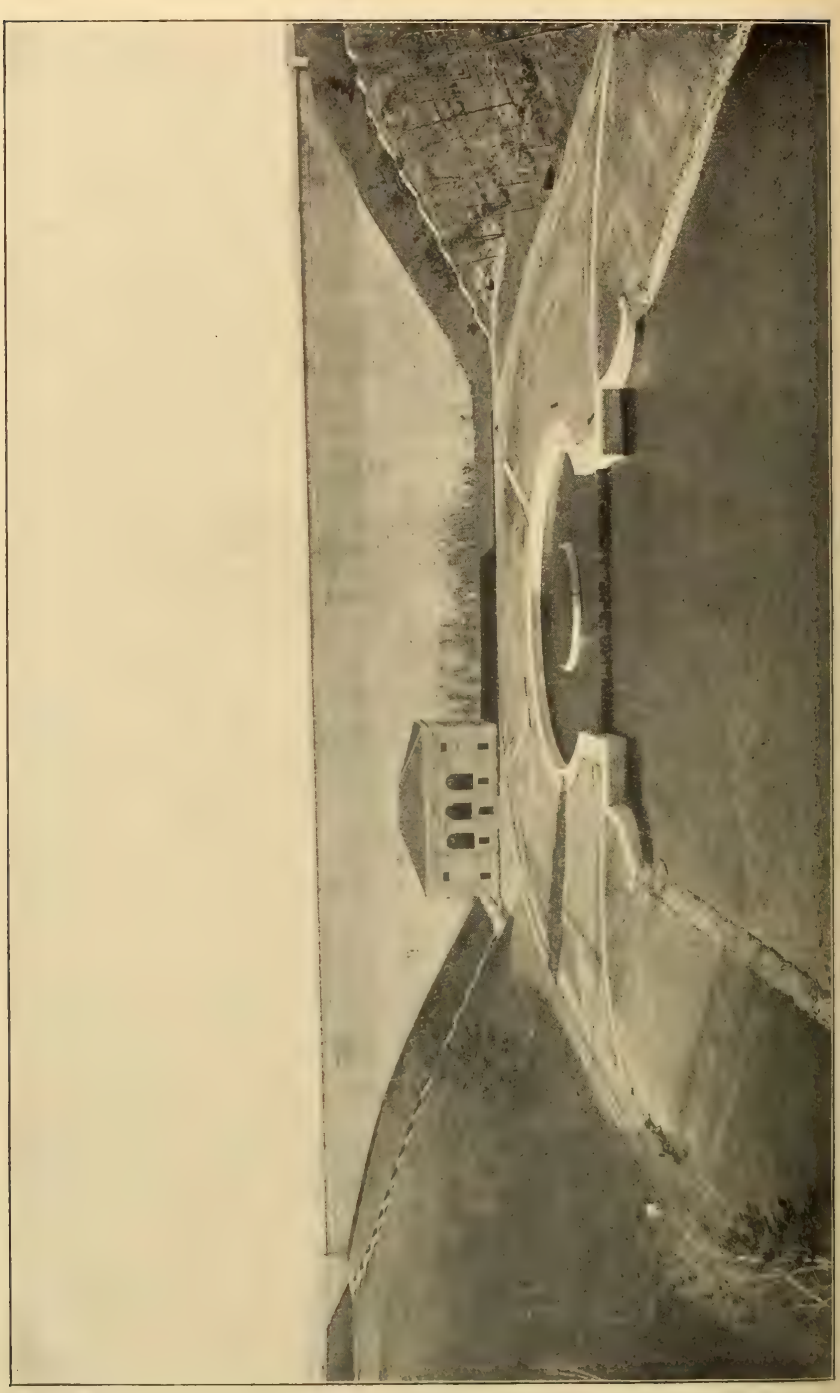


WACHUSETT RESERVOIR—ARCH BRIDGE AND HIGHWAY EMBANKMENT AT WEST BOYLSTON.

SITE OF WACHUSETT DAM—TEMPORARY DAM WITH WASTE-WAY AND CONDUIT CONNECTING WITH TUNNEL.



WACHUSETT DAM—EXCAVATION AT TIME OF BEGINNING MASONRY CONSTRUCTION.

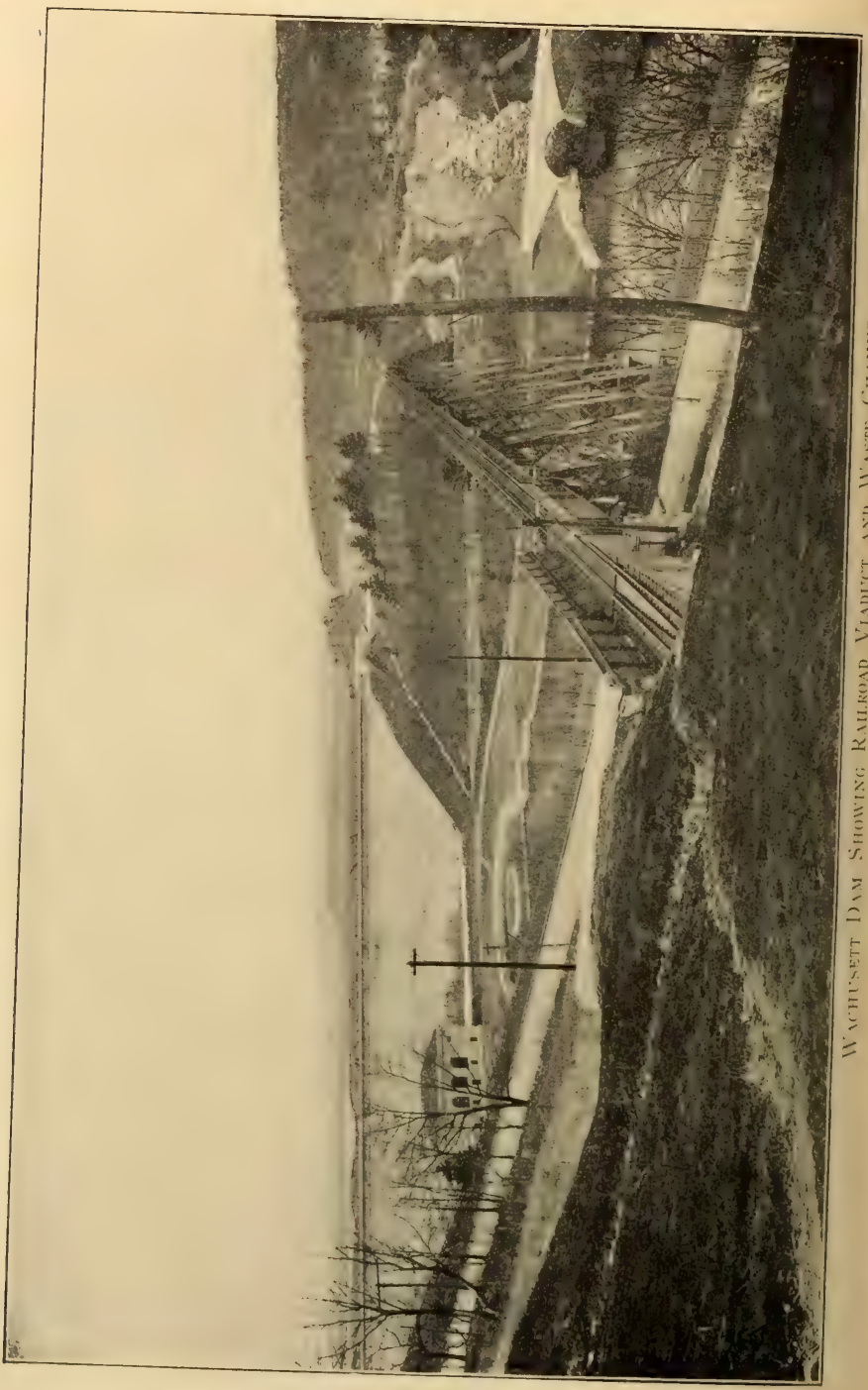


WACHUSETT DAM AND TOWER AND GATE HOUSE.

top of the dam at the point of deepest excavation is 207 feet, and the maximum thickness is about 185 feet. The thickness of the dam 95 feet below high-water level in the reservoir is 81.5 feet, and under the projecting cornice at the top 22.5 feet. The northwesterly end of the dam terminates in a bastion in which, above high-water level, there is a room for the storage of flash boards for use on the waste weir. Beyond the bastion the waste weir extends for 452 feet, on which are cast-iron standards spaced 10 feet apart, containing grooves for flash boards and supporting a bridge.

Passing through the dam, embedded in the masonry, there are four 48-inch cast-iron pipes with their bottoms at elevation 284, above Boston City Base or 111 feet below high water in the reservoir. These pipes connect with circular vertical wells which extend to above high-water mark. Two wells are provided for each pipe, the up-stream one containing two 2½ feet x 6 feet sluice gates at levels 33.5 and 65.5 feet below high water, through which water can be admitted from the reservoir to the down-stream well, and thence into the pipe. Water is admitted to each of the up-stream wells through six ports in the masonry, each 8 feet high and 2.5 feet wide. On the down-stream side of the ports there are three pair of composition grooves in which can be placed screens and stop planks so arranged as to draw the water from the reservoir at any desired depth. The chamber containing the apparatus for operating the gates and screens is built in the dam above high water level and entirely below the top of the dam. The four lines of 48-inch pipes, after passing through the dam, enter the lower gate-chamber which is designed to receive machinery for utilizing the power of the water as it falls from the reservoir to the Wachusett Aqueduct, and also serves as a head-house for the aqueduct. This building contains valves for controlling the flow of water into the aqueduct or into pipes which discharge into a masonry pool 150 feet in diameter, from which it flows into the river channel.

On the north side of the valley, beginning about 1,500 feet above the dam and extending for two miles, and on the south side beginning 2,500 feet above the dam and extending for about half a mile, the elevation of the ground was



WACHUSETT DAM SHOWING RAILROAD VIADUCT AND WASTE CHANNEL.

WACHUSETT RESERVOIR—HIGHWAY BRIDGE OVER WASTE CHANNEL.

lower than the elevation of the water in the full reservoir. Overflow from the reservoir at these points is prevented by earth dikes composed of the soil removed from the bottom of the reservoir. The north dike is in two sections, respectively 4,300 and 6,700 feet long. Its maximum height above the original surface is 65 feet to full reservoir level, and 80 feet to the top of the embankment. The greatest width of the dike is 1930 feet, and it contains 5,861,814 cubic yards of earth, of which 4,955,936 cubic yards is soil removed from the reservoir. To secure water-tightness a cut-off trench, 9,505 feet long, 30 feet wide at the bottom, with slopes of one vertical to one horizontal, was dug parallel with and about 100 feet back from the reservoir side of the dike, through the gravel and coarse sand, to depths of from 30 to 60 feet, until rock or very fine sand nearly impervious to water was generally found. In the bottom of this trench, for a distance of 5,239 feet, sheet piling generally six inches in thickness was driven to a maximum depth of 52 feet below the bottom of the trench. The trench and the embankment above for a width of 100 feet was filled with soil from the reservoir, put in in six-inch layers, watered and rolled. Where the dike is exposed to the waves it is faced between elevation 382 and 400 with riprap of heavy stones about 12 feet in thickness. The south dike is about 2,800 feet long, with a maximum height of 30 feet below the full reservoir level. As in the north dike there is a cut-off trench carried down to rock or impervious material, filled with soil taken from the reservoir. The face of the dike is gravel protected, where exposed to the waves, by granite ripraps, about 12 feet thick.

Reservoirs on the Sudbury Supply.

The Sudbury River, above the point of diversion, has a drainage area of 75.2 square miles, on which eight storage reservoirs have been built by damming the river and its tributaries at various points.

WACHUSETT RESERVOIR—PORTION OF NORTH DYKE SHOWING MAIN CUTT-OFF TRENCH AND SHEET PILING.

WACHUSETT RESERVOIR—PORTION OF NORTH DIKE SHOWING MAIN CUT-OFF TRENCH PARTLY REFILLED WITH IMPERVIOUS SOIL.

The following reservoirs are located on this source:

	Area of water surface (acres).	Available capacity (million gallons).	Elevation above Boston City Base (feet).	Date when completed and filled.	Total height of dam (feet).	Maximum depth of water (feet).
Framingham Reservoir No. 1	143	287.5	169.27	Jan., 1879	22	16
Framingham Reservoir No. 2	134	599.9	177.12	Aug., 1879	26	20
Framingham Reservoir No. 3	253	1,183.5	186.50	Dec., 1878	29	24
Farm Pond	159	167.5	159.25		12	12
Ashland Reservoir	167	1,416.4	225.21	Apr., 1886	58	48
Hopkinton Reservoir	185	1,520.9	305.00	May, 1895	59	53
Whitehall Reservoir	601	1,256.9	337.91		13	18
Sudbury Reservoir	1,292	7,253.5	260.00	Apr., 1898	..	65
Total		13,616.1				

No attempt was made to remove the soil from Framingham reservoirs 1, 2 and 3 at the time of construction, but much of the organic matter was removed from Reservoirs 2 and 3 between the years 1882 and 1886, at a cost of about $200,000. The soil was removed from the bottom of the Ashland, Hopkinton and Sudbury reservoirs at the time of construction.

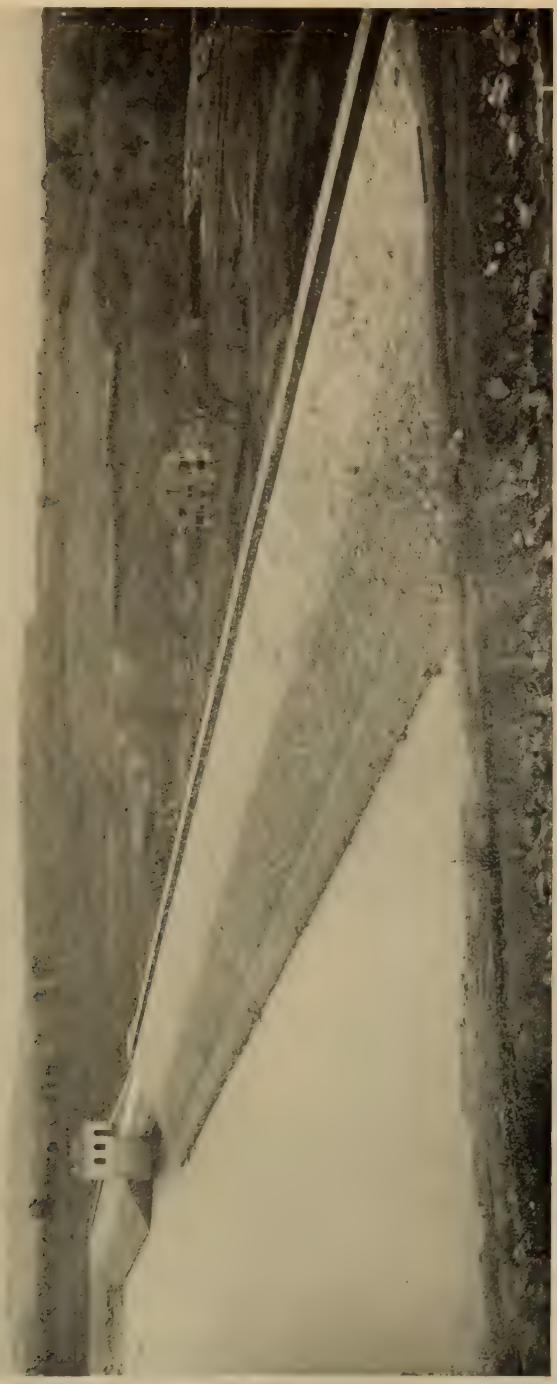
The dams of Framingham Reservoirs 1, 2 and 3 are each constructed with an earth embankment containing a center wall of rubble stone laid in cement mortar, with a waste overfall made of rubble masonry faced with cut granite. Adjacent to each overfall is a gate-chamber containing gates for controlling the water. The dams of Framingham Reservoirs 1 and 3 have a foundation of sand and gravel, while that of Framingham Reservoir No. 2 is ledge under the overfall and gate-chamber and sand or gravel for the remainder of its length. The gate-chambers of Framingham Reservoirs 2 and 3 are connected with the gate-chamber of Framingham Reservoir No. 1 by lines of 48-inch cast-iron pipe, one line from Reservoir No. 2 and two lines from Reservoir No. 3. Through these pipe lines water from these reservoirs can be delivered into the Sudbury River aqueduct without mingling with the water in Reservoir No. 1.

The dams of the Ashland and Hopkinton reservoirs consist of earth embankments 20 feet wide on top, containing a core wall of concrete masonry eight feet thick at the base and three feet at the top, extending to the bed rock, and carefully plastered on the water side with neat cement. The Ashland dam has an outside slope of 2½ to 1, covered with soil, an inner slope of 1½ to 1, covered with paving 15 inches thick, to a berm 6 feet wide 13 feet below the top of the dam, and a 1.65 to 1 slope, covered with riprap, below the berm. The Hopkinton dam has an outside slope of 2 to 1 from the top about half way down the slope, and 2½ to 1 below that point, and an inner slope of 2 to 1 with a berm 6 feet wide 13 feet below the top of the embankment. The inner slope is paved above the berm and riprapped below. At both the Hopkinton and Ashland dams a wasteway is placed at one end of the dam and the waste water is returned to the stream through a paved channel built in steps following the contour of the hillside.

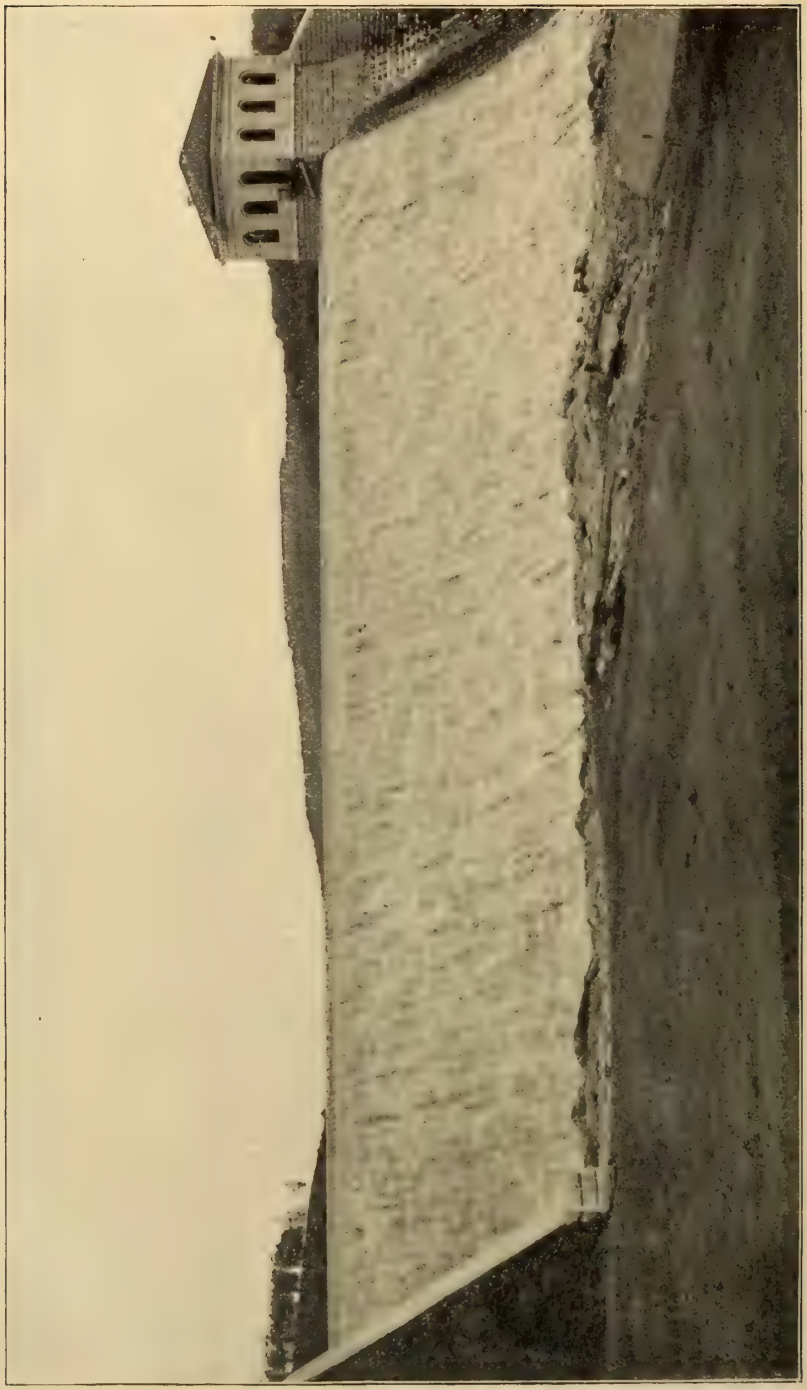
The dam of the Sudbury Reservoir consists of an earth embankment with concrete masonry core wall extending to bed rock, with a granite masonry wasteway and gate-chamber situated near the middle of the structure. The dam is 1,865 feet long, including the wasteway 300 feet in length. The embankment is 14 feet wide at the top and has an outer slope of 2 to 1 from the top to a berm 8 feet wide 22 feet below, and 2½ to 1 below that point. The inner slope is paved and has a slope of 2 to 1 with a berm 6 feet wide 13 feet below the top of the dam.

Lake Cochituate.

Lake Cochituate, situated about 18 miles west of Boston, is a natural pond or chain of ponds about 3½ miles in length. It has an area of 776 acres, and a watershed of 18.87 square miles. By the construction of a dam at the outlet it was raised 8 feet in 1848 and 2 feet additional in 1859. When the water was first taken no special preparation for its use for water supply purposes was made by the removal of soil, but in 1901-02, two areas aggregating about 80 acres where the water was shallow and the mud surface was exposed whenever the lake was drawn down, were improved at a cost of about $102-



SUDBURY DAM—UPPER SIDE



SPILLWAY OF SUDBURY DAM.

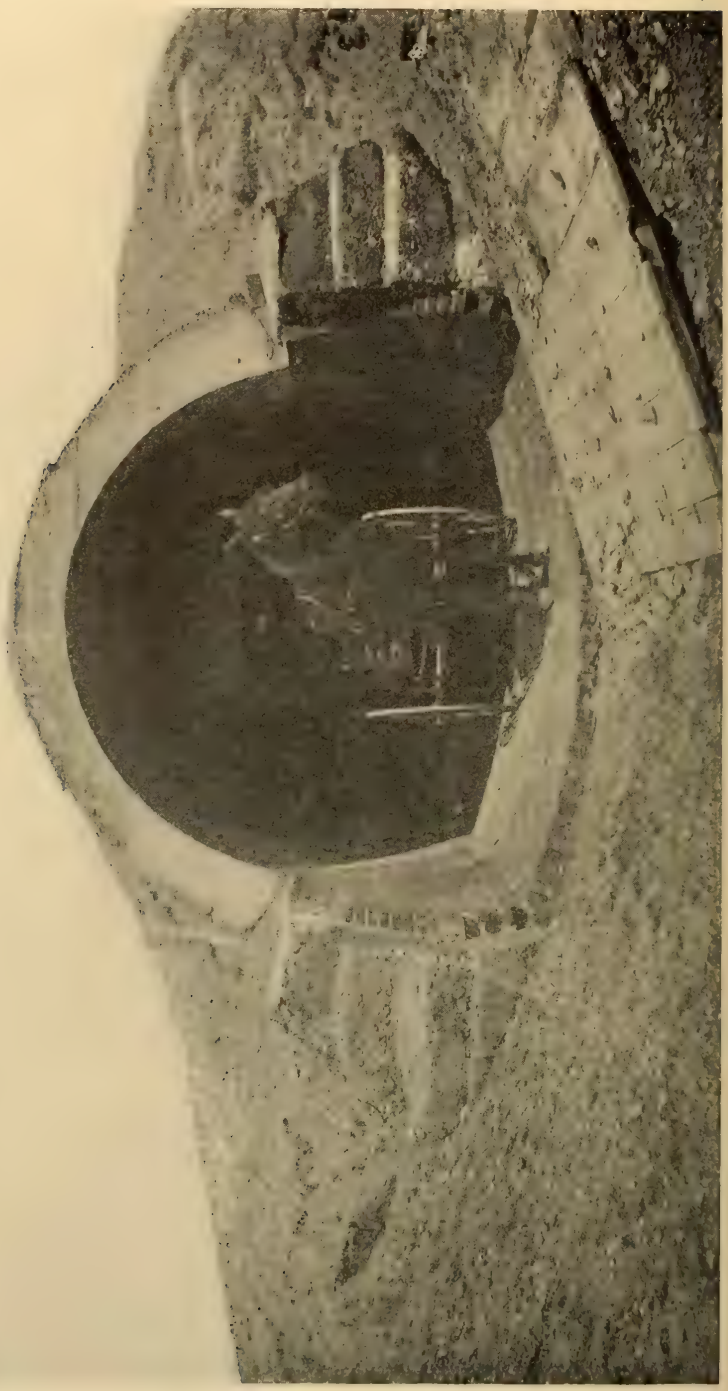
000 by the removal of the organic matter and excavating so as to give a depth of 10 feet of water at high water.

Situated near the lake are two ponds the waters of which can be drawn into the lake. The larger of these, Dudley Pond, has an area of 81 acres, and an available capacity of 250,000,000 gallons. Dug Pond has an area of 44 acres and an available capacity of 150,000,000 gallons.

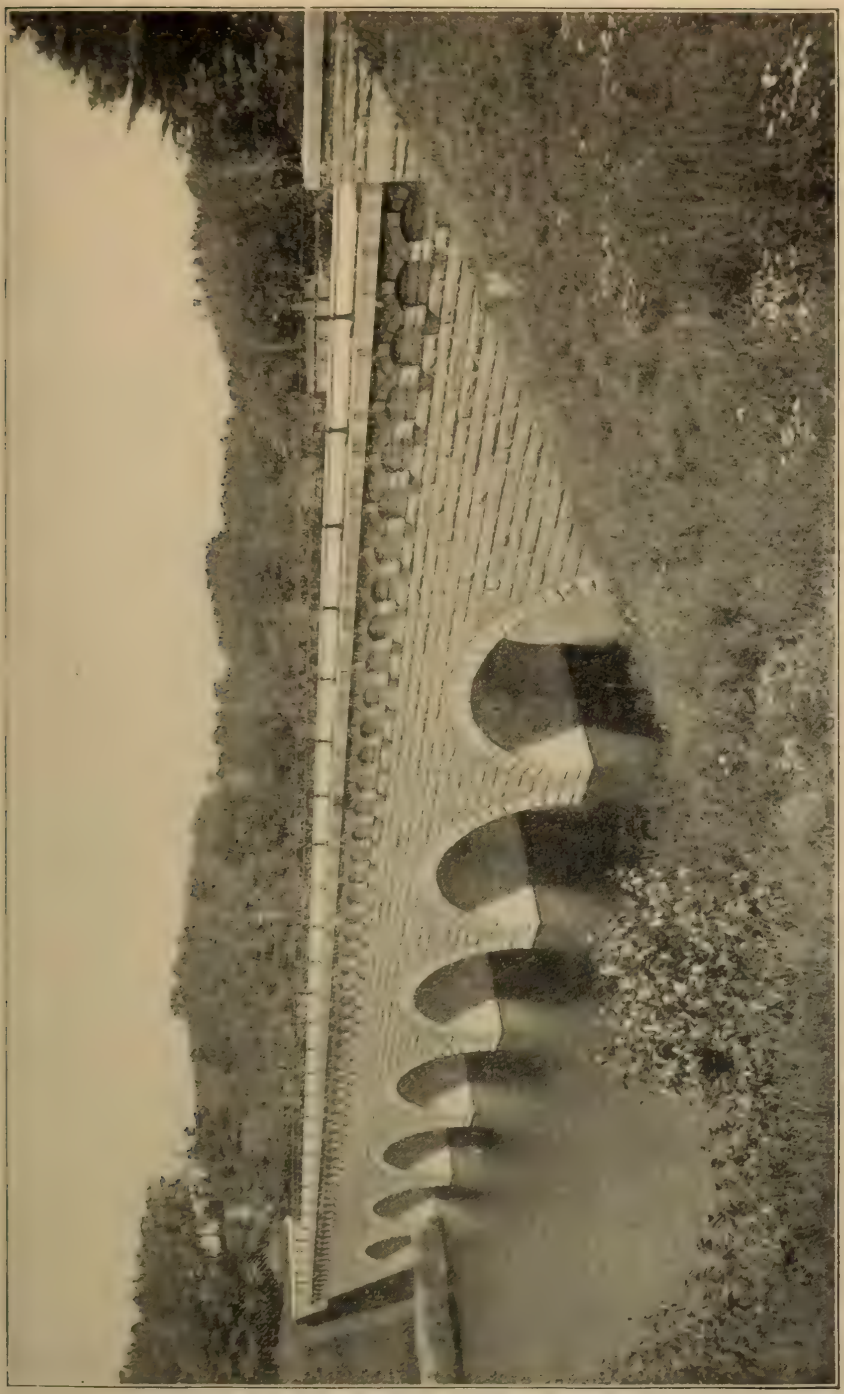
Wachusett Aqueduct.

The Wachusett Aqueduct conveys water from the Wachusett Reservoir to the Sudbury Reservoir, a distance of 12 miles. The first two miles is a rock tunnel followed by seven miles of masonry aqueduct, including a bridge over the Assabet River and 3 miles of open channel. The tunnel section has a fall of 1 foot in 5,000, is lined for about one-half of its length with brickwork 12 inches thick, and where lined is 12 feet 2 inches wide and 10 feet 10 inches high. The masonry aqueduct has a fall of 1 foot in 2,500, and is 11 feet 6 inches wide and 10 feet 6 inches high. The open channel is 20 feet wide on the bottom and has side slopes of 3 horizontal to 1 vertical. All sections have a capacity of 300,000,000 gallons per day.

The tunnel and covered masonry sections of the aqueduct are built in the general shape of a horseshoe, the covered masonry section having a bottom and sidewalls of Rosendale cement concrete lined with 4 inches of brickwork, covered by a semi-circular arch of Portland cement concrete. The aqueduct crosses the Assabet River on a granite masonry bridge 359 feet long, consisting of seven arches each of 29½-foot span. The aqueduct on the bridge was lined with sheet lead to prevent leakage and consequent damage to the masonry from freezing. In order to prevent erosion of the bottom and sides of the open channel, they were faced with gravel where necessary, and two dams are located across the channel, one at the lower end where it enters the Sudbury Reservoir, and one about midway of its length. The superstructures on the aqueduct consist of two granite buildings, one covering a gaging chamber, the other the terminal chamber at the end of the covered masonry aqueduct.



WACHUSETT AQUEDUCT.



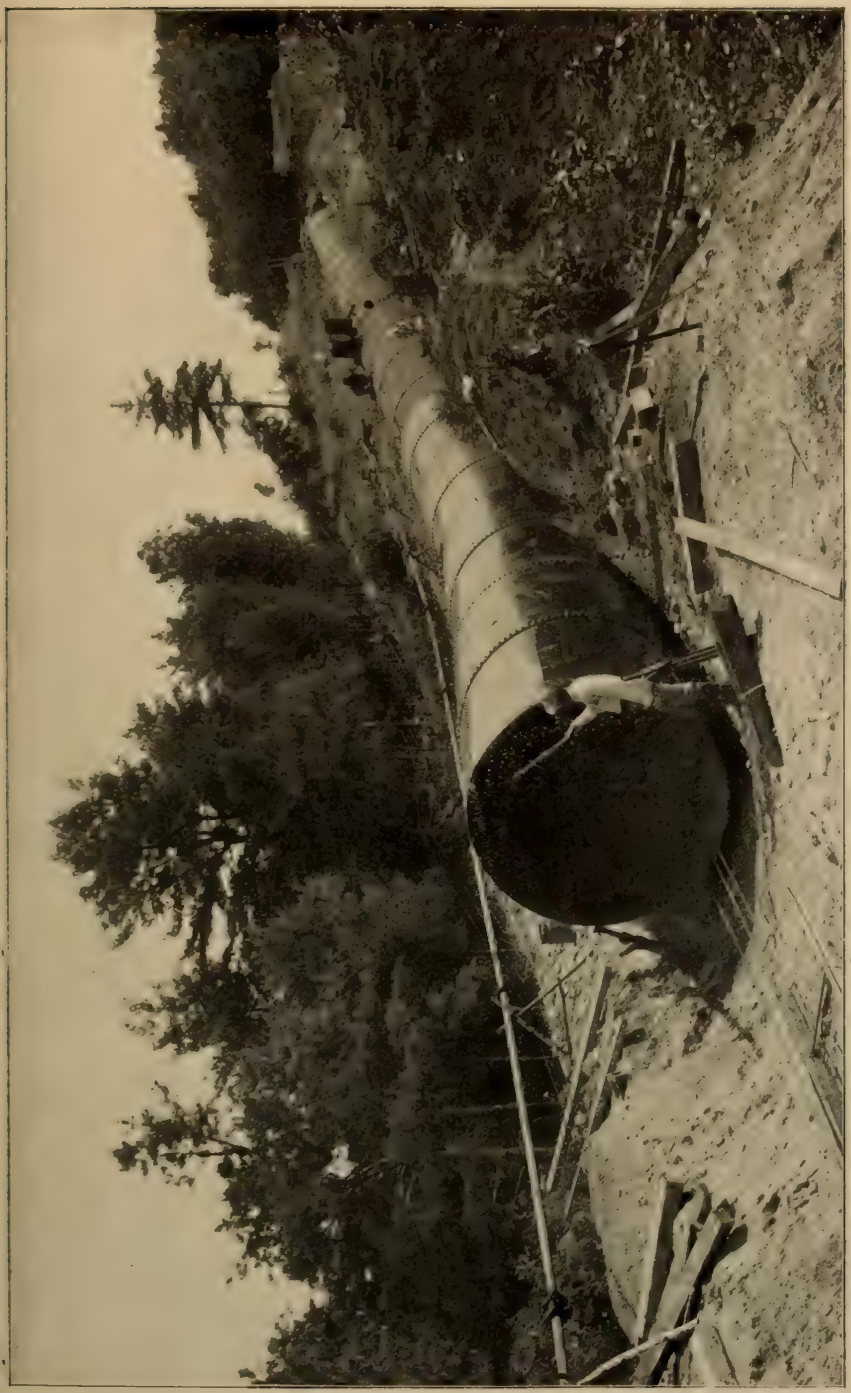
WACHUSETT AQUEDUCT—BRIDGE OVER ASSABET RIVER.

Weston Aqueduct.

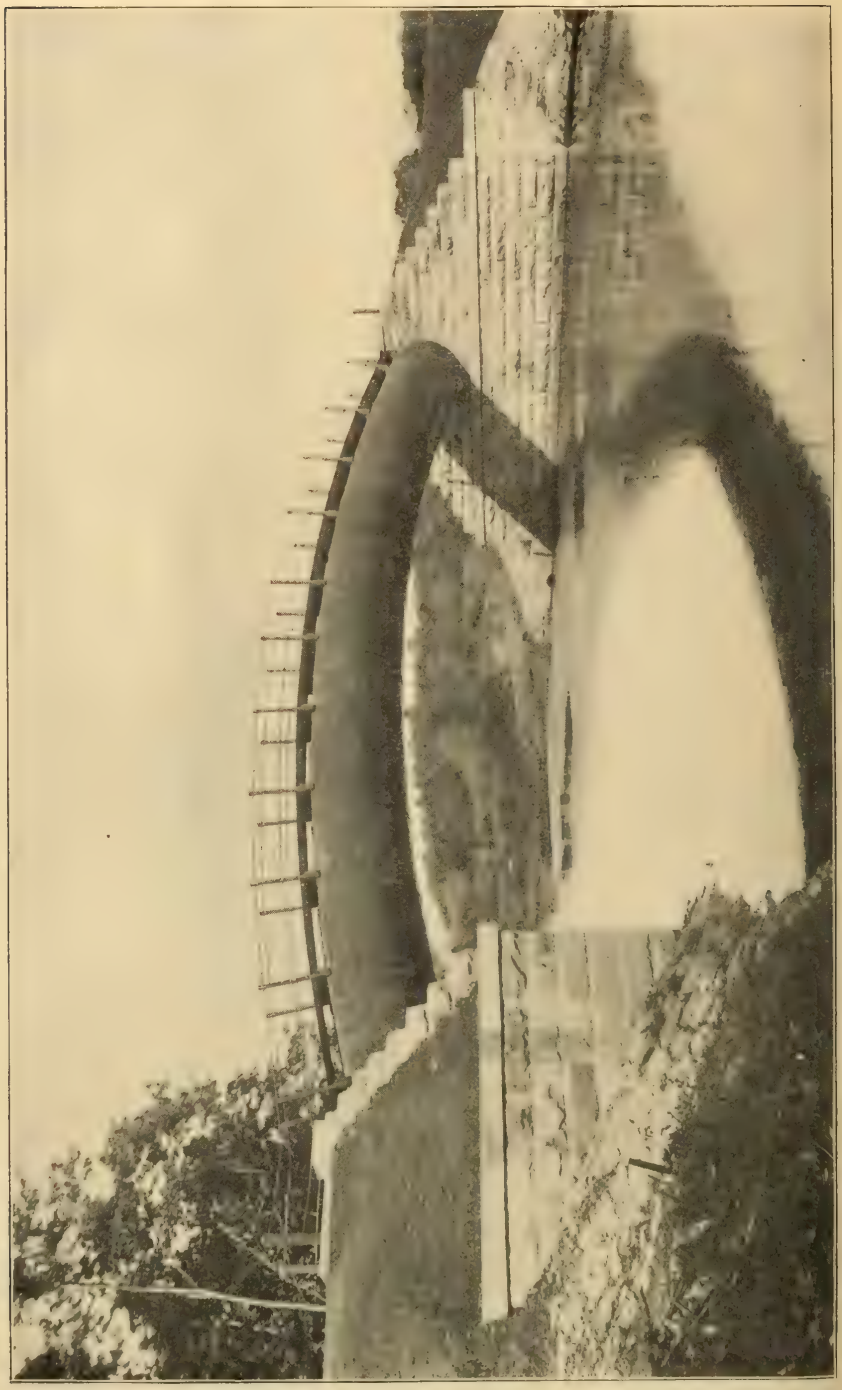
This aqueduct conveys water from the Sudbury Reservoir to a point in the town of Weston a short distance west of the Charles River, and a little more than 10 miles from the State House. The distance from the Sudbury Dam to the terminus of the aqueduct is 13.42 miles. From the Sudbury Dam to the head-house at the beginning of the masonry aqueduct, a distance of 505.5 feet, the water is carried through three lines of cast-iron pipes 60 inches in diameter except for a distance of about 35 feet at the dam. For 3½ miles the masonry aqueduct of horseshoe shape is 10 feet wide by 9 feet 3 inches high, with a fall of 4 feet in 5,000. After passing under the New York, New Haven and Hartford Railroad the fall of the aqueduct is reduced to 1 foot in 5,000, and its size increased to 13 feet 2 inches by 12 feet 2 inches.

In crossing the valleys of the Sudbury River and a depression known as Happy Hollow, steel siphon pipes 7½ feet in diameter are substituted for the masonry structure. At the Sudbury River the pipe line is 3,617 feet long, and at Happy Hollow 1,139 feet. Three lines of pipe will be eventually required to carry the full flow of the aqueduct but only one line has now been laid.

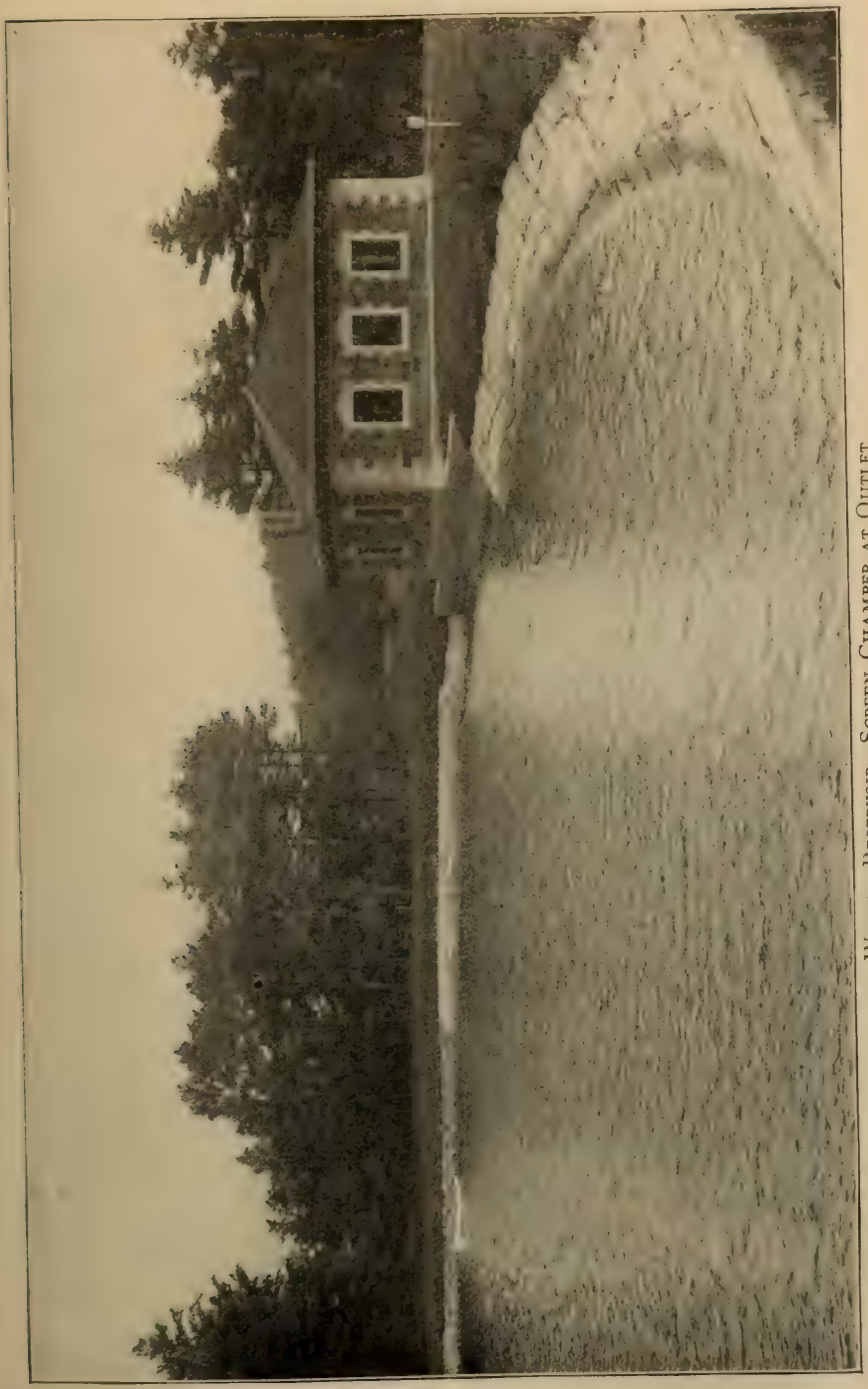
Eleven and one-third miles from the Sudbury Dam the masonry aqueduct discharges into an open channel 1,400 feet long, 12 feet deep and 10 feet wide at the bottom, with gravel side slopes of 3 horizontal to 1 vertical. After passing through this channel, the water enters the Weston Reservoir which with the open channel, takes the place of the aqueduct for about a mile. At the lower end of the reservoir there is a screen chamber from which the masonry aqueduct extends 5,658 feet to the terminal chamber, from which pipes are used to convey the water into the Metropolitan District. Where the aqueduct is built in open trench or on embankments, the bottom and sidewalls are constructed of natural cement concrete lined with one 4-inch course of brick masonry and an arch of Portland cement concrete. On the line of the aqueduct there are five tunnels having an aggregate length of 12,165 feet lined throughout with concrete.



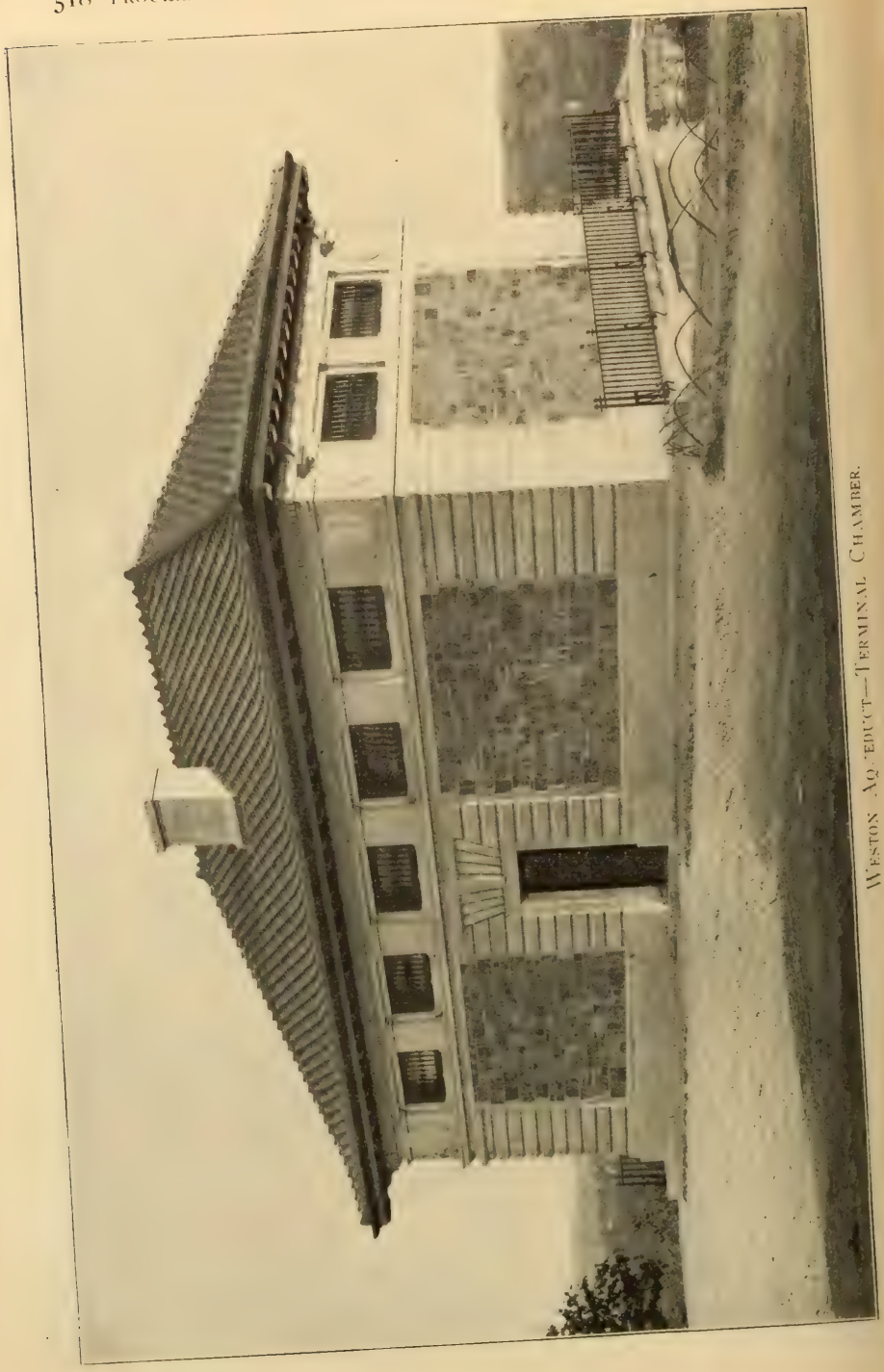
WESTON AQUEDUCT—7½-FOOT STEEL PIPE AT HAPPY HOLLOW SIPHON.



WESTON AQUEDUCT—7½-FOOT STEEL PIPE ARCH ACROSS SUDBURY RIVER.



WESTON RESERVOIR—SCREEN CHAMBER AT OUTLET.



WESTON AQUEDUCT—TERMINAL CHAMBER.

Sudbury Aqueduct.

The Sudbury Aqueduct conveys water from Framingham Reservoirs Nos. 1, 2 and 3, located on the Sudbury River, to the Chestnut Hill Reservoir in the Brighton district of the city of Boston, a distance of 17.4 miles. It is of horseshoe shape, constructed of brick and stone masonry laid in cement mortar. From the beginning at Dam No. 1 to the gate-house at Farm Pond, a distance of 1½ miles, the aqueduct is 7 feet 6 inches wide and 6 feet 10½ inches high, and has a fall of 1 foot in 2,275. From the Farm Pond gate-house to Chestnut Hill Reservoir it is 9 feet wide, 7 feet 8 inches high, and has a fall of 1 foot per mile. It has a capacity of 103,000,000 gallons in 24 hours.

The aqueduct crosses the valleys of Waban Brook and the Charles River on granite masonry bridges. The Waban valley bridge is 536 feet long, and consists of 9 semi-circular arches of 44 feet 8 inches span. The Charles River bridge is 475 feet long, 79 feet above the river, and is formed by 7 arches, the largest one having a span of 129 feet. At the valley of Rosemary Brook two lines of 48-inch and one line of 60-inch cast-iron pipe, each line being 1,800 feet long, take the place of the masonry structure. There are four tunnels on the line of the aqueduct the longest of which is 4,635 feet in length.

This aqueduct was built by the City of Boston, and was completed and first used in 1878.

Cochituate Aqueduct.

This aqueduct is 13.7 miles long and extends from Lake Cochituate to the Chestnut Hill Reservoir. It is egg shaped in section, 5 feet wide, 6 feet 4 inches high, and is built of brick masonry 8 inches in thickness, with the exception of a tunnel 2,410 feet long, which is unlined, and at the crossing of the Charles River where four lines of cast-iron pipes 1,100 feet long are substituted for the masonry structure. Two of these are 30 inches in diameter, one 36 inches and one 40 inches. The masonry portion of the aqueduct has a fall of 1 foot in 20,000.

Chestnut Hill Reservoir.

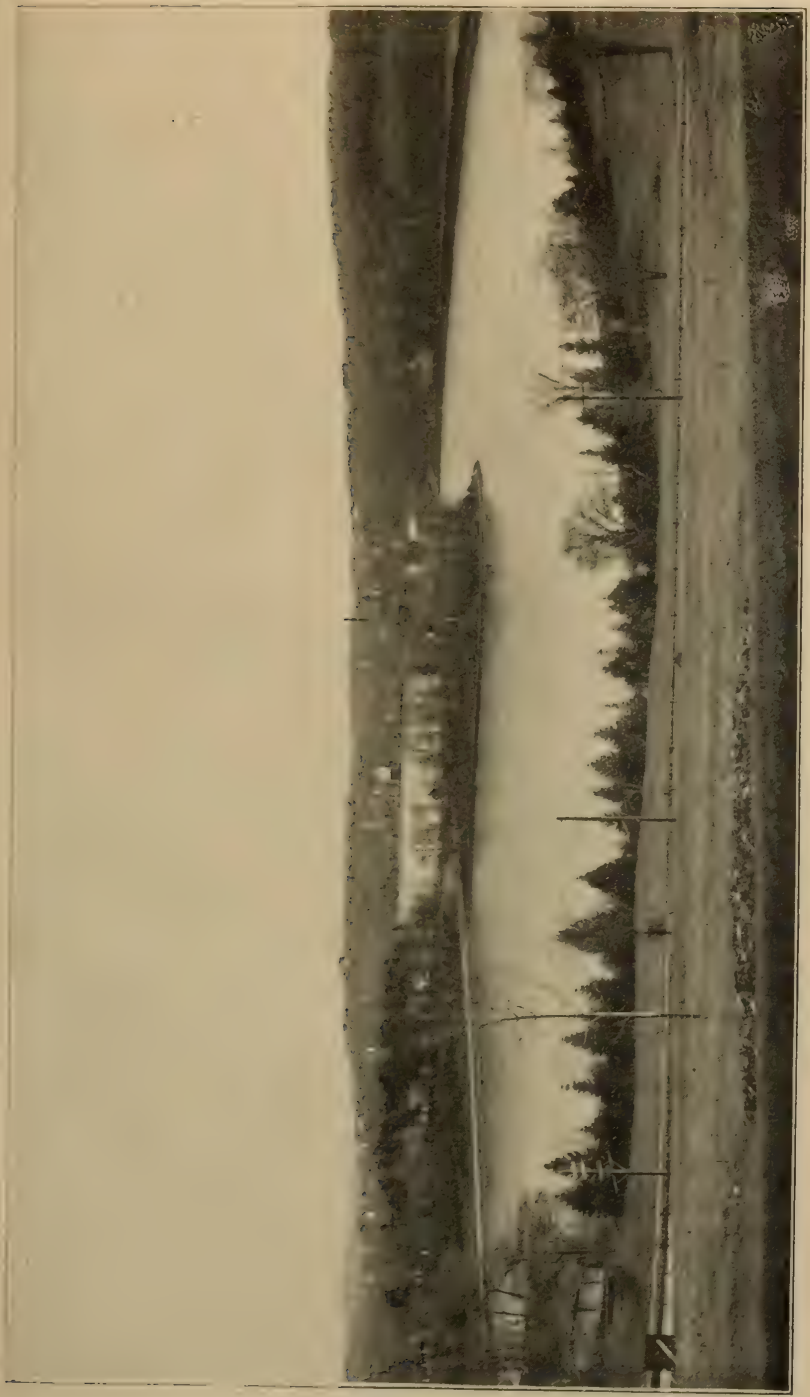
The Chestnut Hill Reservoir is located in the Brighton district of the city of Boston, about five miles from the State House. It receives water from the Sudbury and Cochituate aqueducts, and serves as a storage reservoir from which the pumps at the high and low-service stations draw their supplies. This reservoir was built by the City of Boston, and completed in the year 1870. Its high water mark is 134 feet above Boston city base, and previous to the year 1900 the greater portion of the city of Boston was supplied from this reservoir by gravity.

The reservoir consists of two basins having areas of 87½ and 37½ acres respectively. It was constructed by building a dam 2,000 feet long, with a maximum height of 35 feet, across a valley, removing the soil from the enclosed basin and paving the slopes. The dam is built of earth put on in layers, watered and rolled, and near the center of the dam is a core of clay puddle 10 feet thick at the base and 4 feet at the top. The slopes of both basins of the reservoir are covered with stone paving 2½ feet in thickness, which extends 8½ feet from the top of the bank measured vertically.

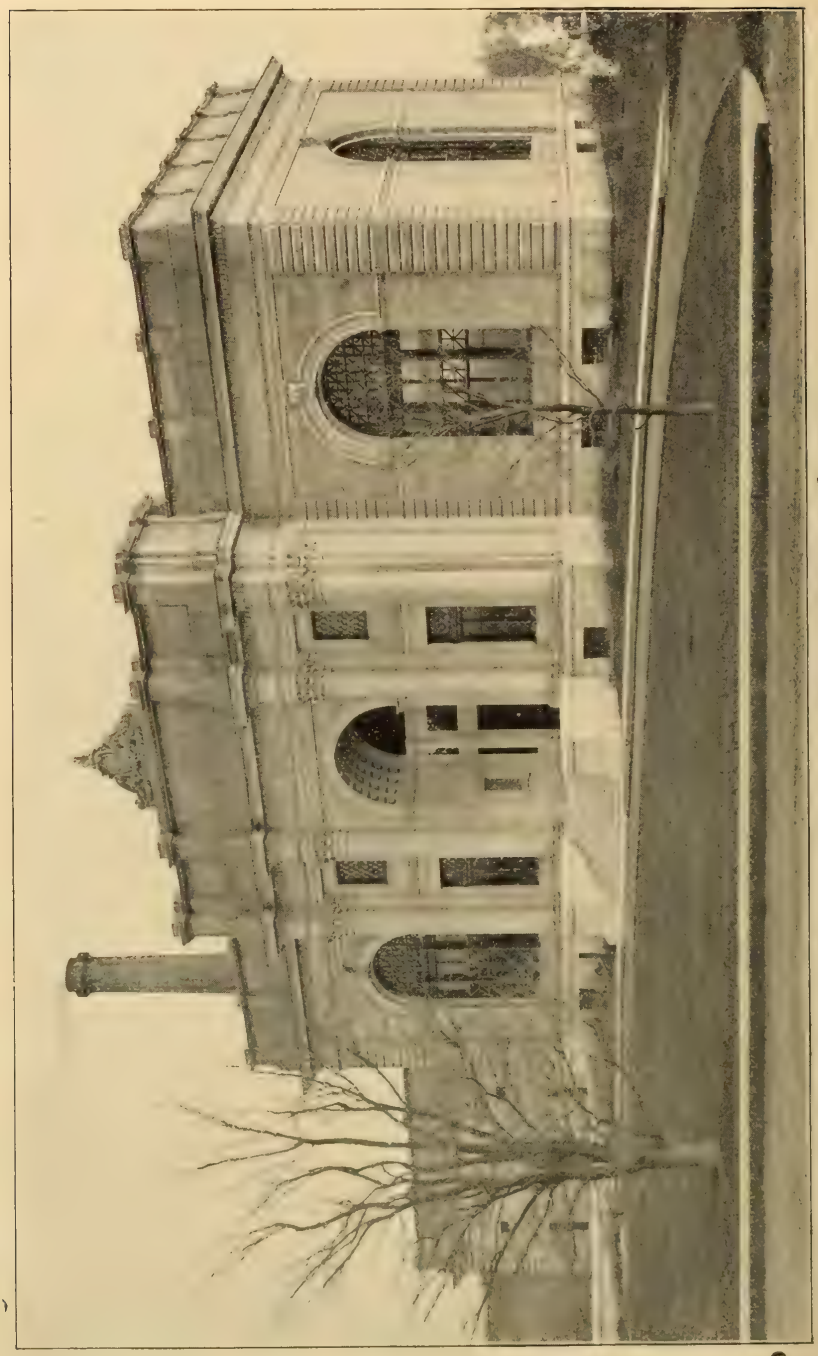
Connected with the reservoir there are five gate-chambers through two of which water is admitted to the reservoir from the Sudbury and Cochituate aqueducts; one contains gates which control the flow between the two basins and also admits water from the Cochituate aqueduct, and through one water is drawn to the two pumping stations. The large gate-chamber at the east end of the reservoir was used as an effluent gate-chamber previous to the year 1900, while water was supplied from the reservoir by gravity, but at present all the gates are closed.

Pumping Stations.

All water delivered into the Chestnut Hill Reservoir by the Sudbury and Cochituate aqueducts is pumped at two stations located on the southeasterly side of the reservoir. At one station water is pumped to supply the higher land in the southern portion of the Metropolitan District; at the other it is pumped into mains leading to Spot Pond, which is the



CHESTNUT HILL RESERVOIR, WITH HIGH AND LOW SERVICE PUMPING STATIONS.

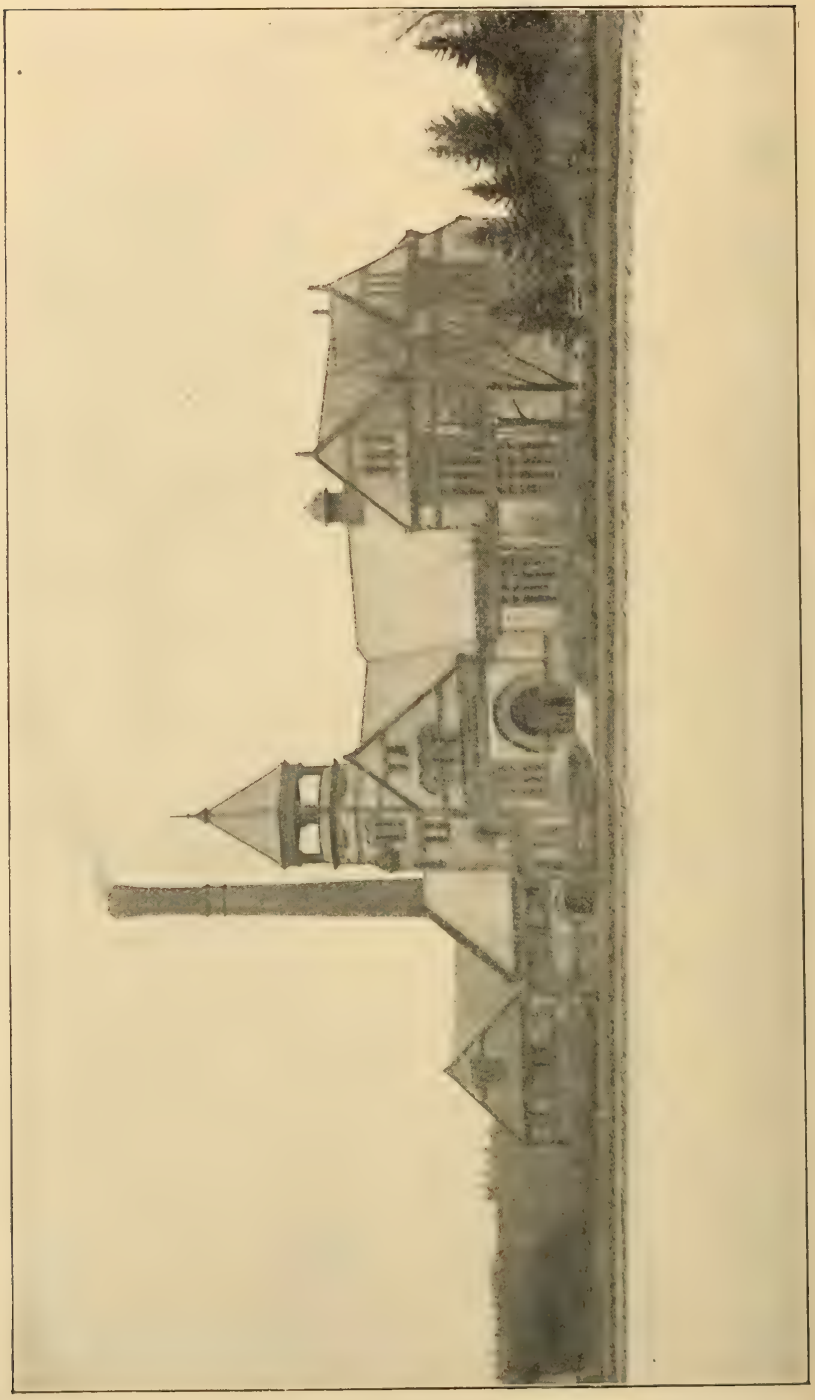


CHESTNUT HILL LOW SERVICE PUMPING STATION.

principal distributing reservoir for the lower portion of the District. On the shore of Spot Pond, in Stoneham, there is a pumping station from which water is pumped to a reservoir supplying the higher levels in the northern part of the District. At two smaller stations, one in the West Roxbury district of Boston and one in the town of Arlington, water is pumped to supply small districts situated above the elevation supplied from the larger stations at Chestnut Hill and Spot Pond.

The low-service pumping sation at the Chestnut Hill Reservoir has exterior walls of buff Bedford Indiana limestone. The building contains an engine room 134 feet by 60 feet, 41½ feet in height from the floor to the under-side of the roof trusses, a boiler room 62 feet by 40 feet, a coal house 89½ feet by 48 feet, a dynamo room 38 feet by 17 feet, and a tower 19 feet square in which is located a steel equalizer and overflow tank 13½ feet in diameter and 33 feet high, having a capacity of 31,000 gallons. The interior facing of the engine room walls is of buff brick with red brick trimmings, and the floor is of green slate tile. The chimney is 125 feet high, 13 feet in exterior diameter at the base and 8 feet at the top under the cap. The flue is 4 feet 6 inches in diameter.

The machinery consists of three 35,000,000-gallon vertical triple expansion crank and fly-wheel engines, designed and built by the Holly Manufacturing Company of Lockport, N. Y., and three vertical fire tube boilers designed by Dean and Main and built by the Atlantic Works of East Boston. The engines have steam cylinders 17, 31¼ and 48 inches in diameter, pump plungers 37 inches in diameter, and both pistons and plungers have a stroke of 60 inches. These engines draw their supply from the Chestnut Hill Reservoir, and raise it from 45 to 60 feet. On the contract trial they gave a duty of 156,322,000-foot pounds per 100 pounds of dry coal. The boilers are 97 7/8 inches inside diameter, 29½ feet high over all, and contain 384 2-inch tubes 15 feet long. A Green economizer, with 144 tubes, is located in the smoke flue between the boilers and the chimney. The coal house has a capacity of 1,000 tons, and is so arranged that loaded cars are run into the building about 15 feet above the floor.



High Service Pumping Station at Chestnut Hill Reservoir.

The high-service pumping station has exterior walls of pink Milford granite with brownstone trimmings. The engine room contains two 8,000,000-gallon Gaskill engines built by the Holly Manufacturing Company, of Lockport, N. Y., one 20,000,000-gallon triple expansion engine designed by E. D. Leavitt and built by the Quintard Iron Works, of New York, N. Y., and one 30,000,000-gallon vertical, triple expansion, crank and fly-wheel engine, designed and built by the E. P. Allis Company of Milwaukee, Wisconsin. The boiler room contains one boiler of the Belpaire type, two internally fired verticle fire-tube boilers, and two externally fired fire-tube boilers.

The principal dimensions and other data relating to the engines and boilers at this station are as follows:

	Engines.		
	Gaskill.	Leavitt.	Allis.
Erected	1887	1895	1898
Diameter of high pressure cylinder (ins.)	21	13 7-10	30
Diameter of intermediate pressure cylinder (ins.)	..	24.375	56
Diameter of low pressure cylinder (ins.)	42	39	87
Diameter of pump plunger (ins.)	25	17.5	42
Stroke of pumps	36	48	66
Normal revolutions per minute	18½	50	18
Cost	$24,000	$140,000	$140,000
Duty per 1,000 pounds of dry steam on official trial (foot pounds)			178,497,000
Duty per 100 pounds of coal (foot pounds)			173,869,000

	Boilers.		
	Belpaire.	Vertical Tubular.	Horizontal Tubular.
Diameter (ins.)	90	98	64
Length in feet	34.33	24.33	18.42
Thickness of shell (ins.)	.8	27/32	17/32
Number of tubes	201	392	102
Diameter of tubes (ins.)	3	2	3
Length of tubes (ft.)	16	14	17.88
Heating surface (sq. ft.)	3000	2207	1475

These engines pump water from the Chestnut Hill Reservoir for the supply of the southern high-service district, raising it from 120 to 130 feet into the Waban and Fisher Hill reservoirs.

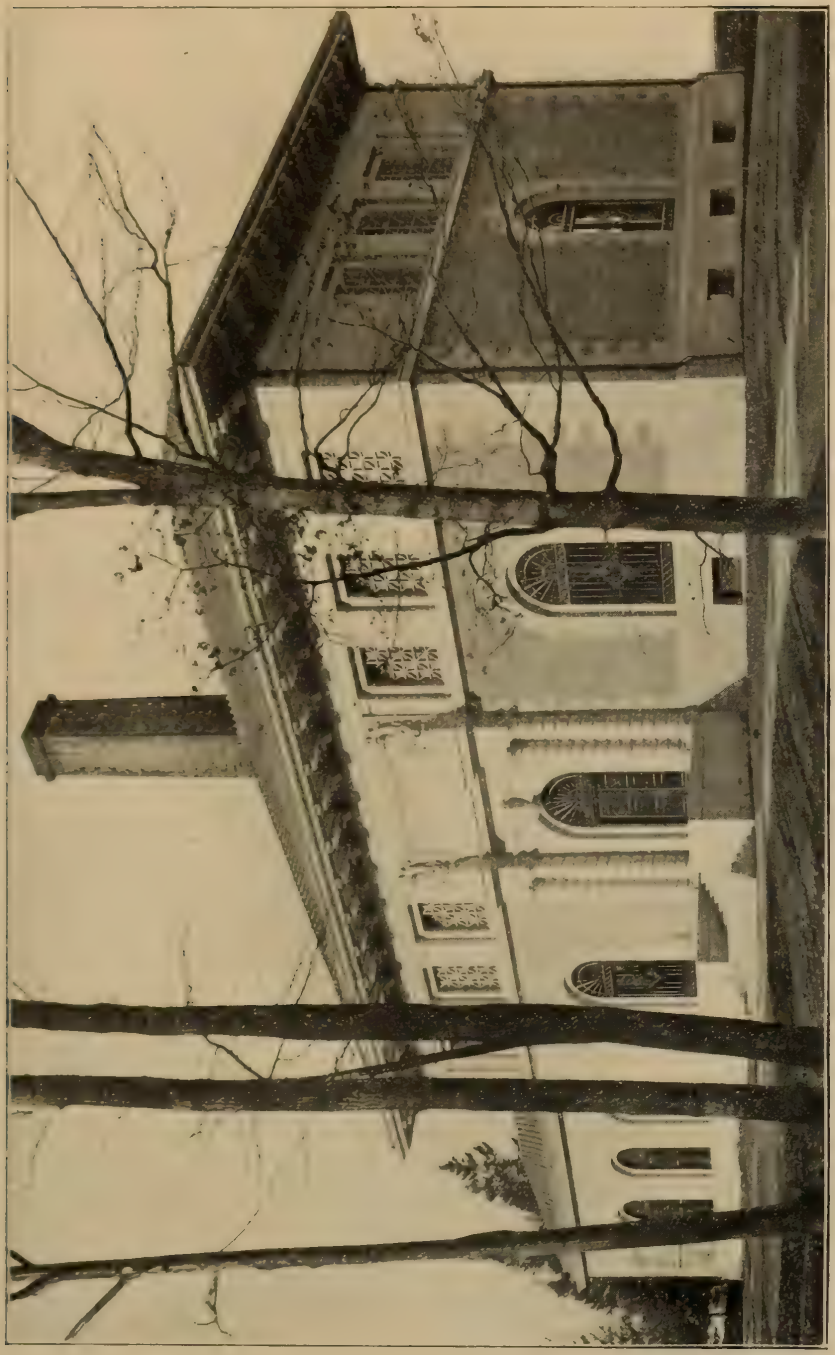
The Spot Pond pumping station building has exterior walls

of gray Roman brick, with trimmings of buff Indiana limestone above a heavy base of pink Milford granite. The roof is covered with red Spanish tiles. The building contains an engine room 105 feet by 60 feet, a dynamo room 49 feet by 16 feet, a boiler room 53 feet by 49 feet, and a coal house 71 feet 8 inches by 40 feet, having a storage capacity of 1,000 tons. The chimney is 125 feet high, 11 feet square at the base, 9 feet at the top, with a flue 4 feet in diameter. The engine room contains at present two engines, one of 10,000,000 gallons daily capacity, designed by E. D. Leavitt for the City of Boston, and erected by the Blake Manufacturing Company in 1895 at the Mystic pumping station, whence it was removed in 1899, and one of 20,000,000 gallons daily capacity erected by the Holly Manufacturing Company of Lockport, N. Y. The engine room contains space for a third engine.

The Leavitt engine has steam cylinders 21 inches and 42 inches in diameter, operating two differential plunger pumps. The plungers have diameters of 14 7/8 and 21 inches, and both pump plungers and steam pistons have a stroke of 48 inches. The Holly Manufacturing Company's engine has steam cylinders 22 inches, 41½ inches and 62 inches in diameter, pump plungers 30½ inches in diameter, and both pistons and plungers have a stroke of 60 inches.

The boiler room contains three vertical internally fired fire tube boilers 92 inches in diameter, 29 feet 4½ inches long, containing 256 2¼-inch tubes 15 feet long. The boiler feed water is heated by passing through a Green economizer containing 144 tubes. By these pumps water is raised from Spot Pond 108 feet to the Fells Reservoir, and 137 feet to the Bear Hill Reservoir, and from these reservoirs distributed to the elevated portions of the northern part of the Metropolitan District.

The Arlington pumping station is located in the town of Arlington, near the Boston and Maine Railroad. It contains two duplex direct acting pumps, each of 750,000 gallons capacity in 24 hours, one boiler of the locomotive type 56 inches in diameter, 18 feet long, containing 60 4-inch tubes, and one vertical internally fired boiler 72 inches in diameter, 9 feet 3 inches long, containing 350 2-inch tubes 6 feet long. These pumps take water from a main under a pressure of about 30 pounds, and raise it to a standpipe the top of which is 443



SPOT POND PUMPING STATION.

feet above Boston city base, giving a pressure of about 160 pounds on the pumps.

The West Roxbury pumping station, located in the West Roxbury district of the city of Boston, contains two compound duplex condensing pumps made by Henry R. Worthington, each having a capacity of 1,000,000 gallons in 24 hours. Steam is supplied by two boilers 54 inches in diameter, 9 feet long, containing 184 2-inch tubes. These pumps draw their supply from a main under a pressure of about 38 pounds, and raise it under a pressure of 97 pounds to a standpipe the top of which is 376 feet above Boston city base.

Distributing Reservoirs.

Connected with the Metropolitan Water Supply there are six reservoirs and two standpipes belonging to the Metropolitan Works, and five reservoirs and eleven standpipes belonging to the several cities and towns. Two of the local reservoirs and several of the standpipes are not in use at the present time.

The location, elevation and capacity of all the distributing reservoirs is as follows:

Reservoirs.

Name. Location.	Elevation.	Capacity.	Service.	Owner.
Spot Pond, Stoneham..	163	1,800,000,000	Low	Met. W. W.
Mystic, Medford	157	26,000,000	Low	Met. W. W.
Fells, Stoneham	271	41,353,000	No. high	Met. W. W.
Bear Hill, Stoneham....	300	2,452,000	No. high	Met. W. W.
Waban Hill, Newton...	264.5	13,500,000	So. high	Met. W. W.
*Forbes Hill, Quincy...	192	5,116,000	So. high	Met. W. W.
Fisher Hill, Brookline.	251	15,400,000	So. high	Boston.
Chelsea, Chelsea	196.6	1,000,000	No. high	Chelsea.
Revere, Revere	194.5	1,818,000	No. high	Revere.
*E. Boston, E. Boston..	...	5,600,000	Low	Boston.
*Parker Hill, Roxbury.	229	7,200,000	So. high	Boston.

Standpipes.

Name. Location.	Elevation.	Capacity.	Service.	Owner.
Forbes Hill, Quincy.....	252	340,000	So. high	Met. W. W.
Arlington, Arlington....	443.2	564,000	No.Ex.high	Met. W. W.
W. Roxbury, W. Roxb'y	376.3	135,300	So.Ex.high	Boston.
Orient Hgts., E. Boston	204.4	135,300	No. high	Boston.
†Everett, Everett	221.9	141,000	No. high	Everett.
Lexington, Lexington...	385.3	185,000	No.Ex.high	Lexington.
Lexington, Lexington...	387.4	105,750	No.Ex.high	Lexington.
*Malden, Malden	250.4	1,156,700	No. high	Malden.
†Medford, Medford	232.5	432,000	No. high	Medford.
Nahant, Nahant	170	502,300	No. high	Nahant.
Quincy, Quincy	249	432,000	So. high	Quincy.
Swampscott, Swampsc't.	200	611,000	No. high	Swampscott.
Watertown, Watertown.	229.7	376,000	So. high	Watertown.

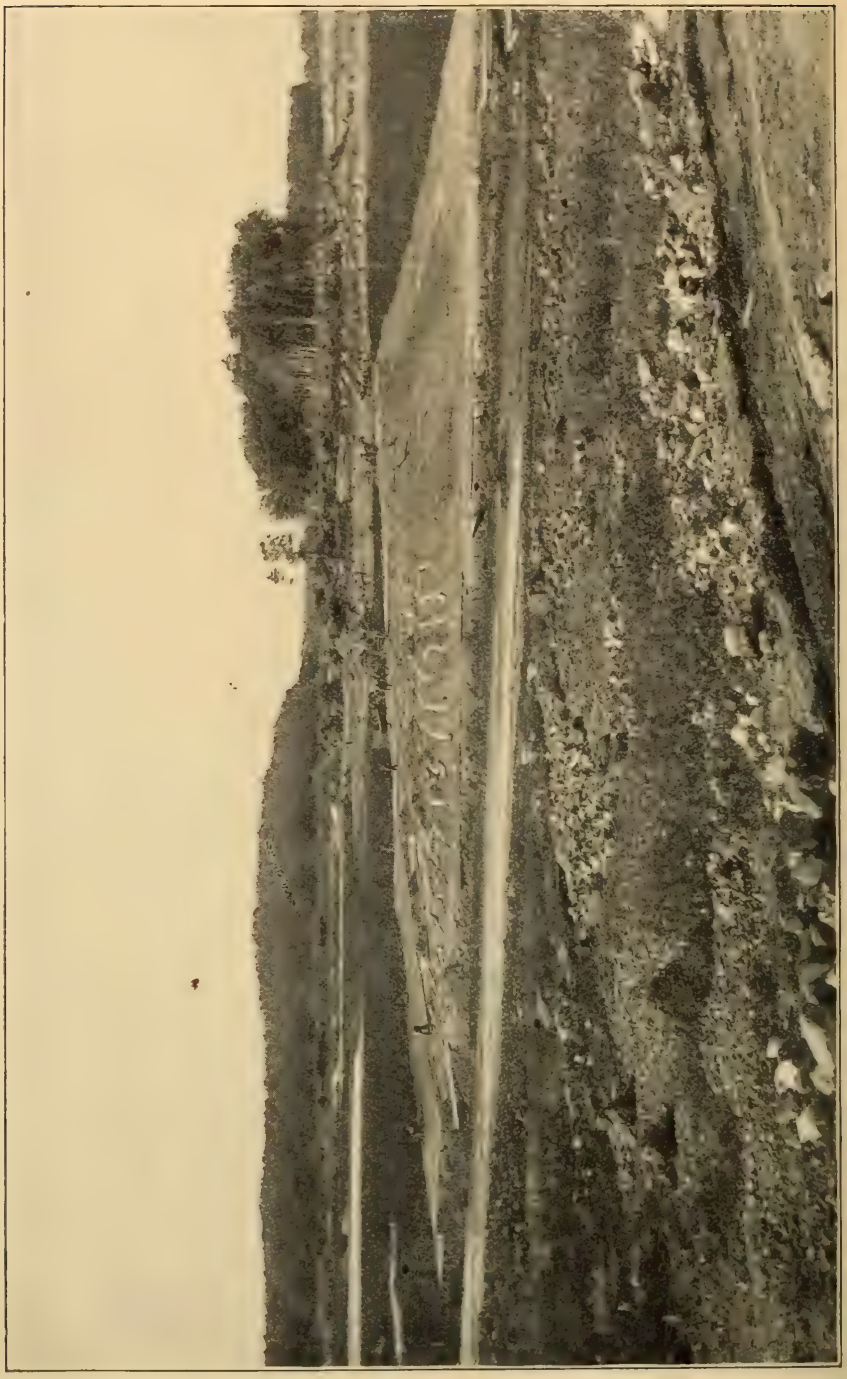
* Kept full of water for use in emergencies. † Not in use at present.

Spot Pond.

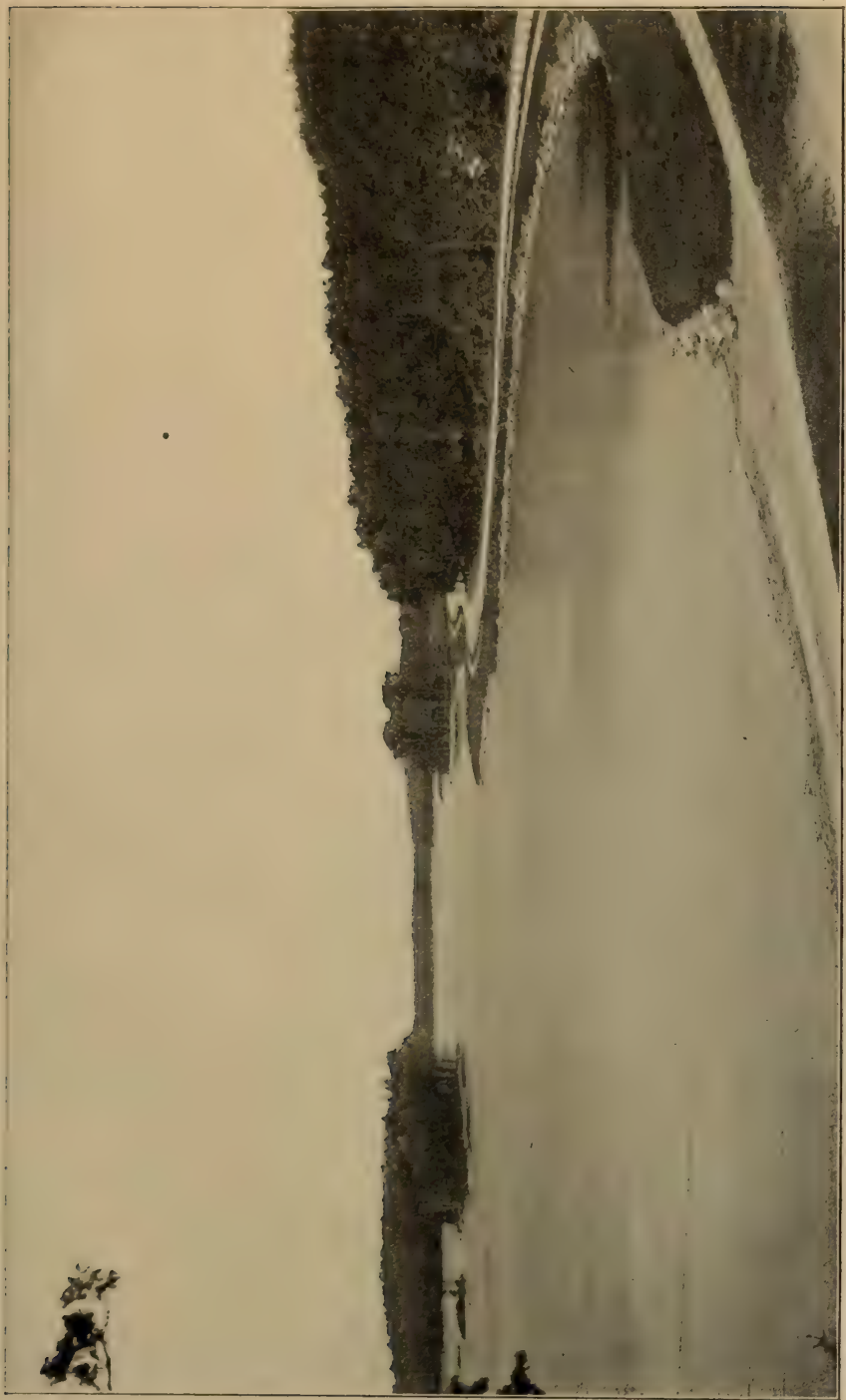
Spot Pond, the largest distributing reservoir, has an area of 308.7 acres and is situated in the northern part of the Metropolitan District in the town of Stoneham, about eight miles from the State House and eleven miles from the Chestnut Hill Reservoir. It has been formed by raising and improving a large natural pond which, previous to the construction of the Metropolitan Works, was used as a source of supply for the cities of Malden, Medford and the town of Melrose. The improvement of the pond was made by lowering its surface 12 feet, thus exposing the greater part of the bottom, and then excavating the mud so as to give a clean gravel or sand bottom over the greater part of the exposed area. In places where the mud was so deep that it could not be removed without going below the level of the water in the pond, the mud was covered with clean gravel or sand 12 inches in thickness. The earth was also excavated from the shallow portions of the pond so as to give everywhere a depth of 15 feet of water when the pond is full.

The pond was raised 9 feet above its old level, necessitating the building of six dams with concrete corewalls from 165 to 621 feet long, and from 10 to 28 feet in height, and four earth dikes; also the construction of a system of drainage to care for water which, by the construction of the dams, is prevented from entering the pond. This drainage system consists of 2,200 feet of open channel, 1,600 feet of 24-inch vitrified pipe, 1,050 feet of concrete masonry conduit 4 feet wide, 3½ feet high, and 2,400 feet of 30-inch cast-iron pipe.

The drains collect the water from 766 acres which formerly drained into the pond, and discharge it into the brook which was the outlet of the pond previous to its improvement. Water enters and leaves the pond at two points located about 3,000 feet apart. At each of these points there is a concrete masonry chamber located at the shore, in which there are sluice gates for controlling the flow of water. From each chamber two inlets into the pond are provided so as to draw water from different depths. From the east chamber there is a concrete masonry conduit 5 feet high, 4.5 feet wide, extending 565 feet into the pond, with its invert 25.2 feet below high water. The



SPOT POND—COVERING DEEP MUD WITH SAND.

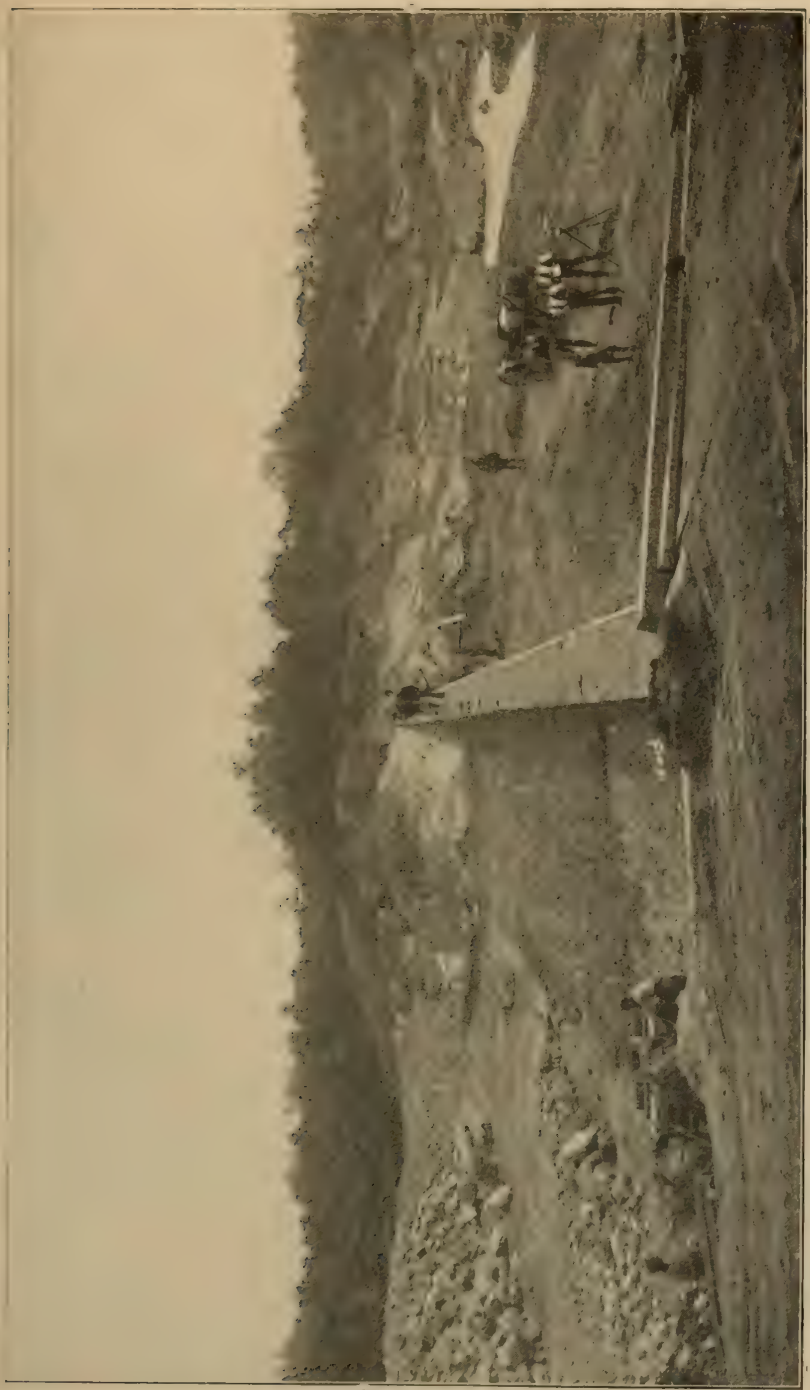


SPOT POND—VIEW OF NORTHWESTERLY PART AFTER IMPROVEMENT.

high level inlet consists of a 48-inch pipe 58 feet in length. From the south gate-chamber a concrete masonry structure containing two conduits placed one above the other, extends 200 feet into the pond. The invert of the lower conduit is 26 feet below high water, and the opening into the upper conduit is in the top of the masonry structure 12 feet below high water. From the gate-chambers cast-iron pipes convey the water into the Metropolitan District.

Fells Reservoir.

The Fells Reservoir, which is the principal distributing reservoir for the northern high-service district, is located in the Middlesex Fells about 2,500 feet east of Spot Pond, and its high water level is 271 feet above Boston city base, or 108 feet above the level of Spot Pond. It covers 8½ acres located in a natural rocky basin which, by the construction of five dams having an aggregate length of 930 feet, has been converted into a reservoir of irregular outline, which, when full, has a capacity of 41,353,000 gallons. All of the dams have corewalls of natural cement concrete 3 feet thick at the top, which are carried down with a batter of 1 in 12 on each side to the solid rock for their entire length. The tops of the walls are 2 feet above high water, and their heights vary from 15 to 34 feet. The faces of the walls next the reservoir are plastered with Portland cement mortar. Embankments of selected material put on in 4-inch layers and rolled with grooved rollers, were built on both sides of each corewall and covered, on the side next to the reservoir, with a 4 to 1 slope of fine broken stone 10 inches in thickness, extending from a point 1½ feet above high water mark to a point 4 feet below, and below that point the embankments have a slope of 2 to 1 covered with Portland cement concrete 4 inches in thickness. At elevation 265 or 6 feet below high water the reservoir is divided by a natural ridge of rock and two walls of Portland cement concrete into two basins, the easterly of which has a capacity of 10,440,000 gallons, and the westerly 15,359,000 gallons. Water is supplied to the reservoir from the pumping station at Spot Pond through a 36-inch force main which enters the north end of the reservoir and is laid through the west



FELLS RESERVOIR—CONCRETE CORE WALL AND PARTIALLY CONSTRUCTED EMBANKMENT.

basin, supported on concrete piers, to the gate-house at the south end of the reservoir. The portion of the gate-house below the ground level is built of Portland cement concrete faced on exposed sides with granite to a point 6 feet below high water mark. The structure contains 6 chambers provided with gates, so that the water can be delivered from the pumps into either basin or to the District, and can also be drawn from either basin independently. The gate-house also contains a measuring weir 6 feet in length for determining the capacity of the pumping engines. The superstructure of the gate-house is built of seam-faced granite with trimmings of Deer Isle granite, and the roof is covered with red tiles.

Mystic Reservoir.

This reservoir is situated near Tufts College in the city of Medford, and was built in 1863 by the City of Charlestown in connection with works for supplying water from Mystic Lake. It was taken from the city of Boston and became a part of the Metropolitan Water Works on January 1, 1898, and is used as a low-service reservoir, being 6 feet lower than Spot Pond. It is about 550 feet long by 350 feet wide at the level of the granite coping which surrounds the reservoir on the top of the embankment. The embankments are of earth, 19 feet 4 inches wide at the top, with 1½ to 1 slopes. The reservoir is lined with clay puddle 24 inches in thickness, covered on the bottom with Rosendale cement concrete 3 inches in thickness, and on the slopes with a paving of brick 8 inches thick laid in cement mortar. The reservoir is divided into two basins by an embankment, the top of which is 5 feet below high water mark. The depth of water in the reservoir when full is 22 feet. A gate-chamber at the south-east corner of the reservoir contains gates for controlling the flow of water to and from the reservoir, and there is also a chamber in the embankment on the easterly side of the reservoir through which water was pumped into the reservoir when it was used in connection with the supply from Mystic Lake.

Forbes Hill Reservoir.

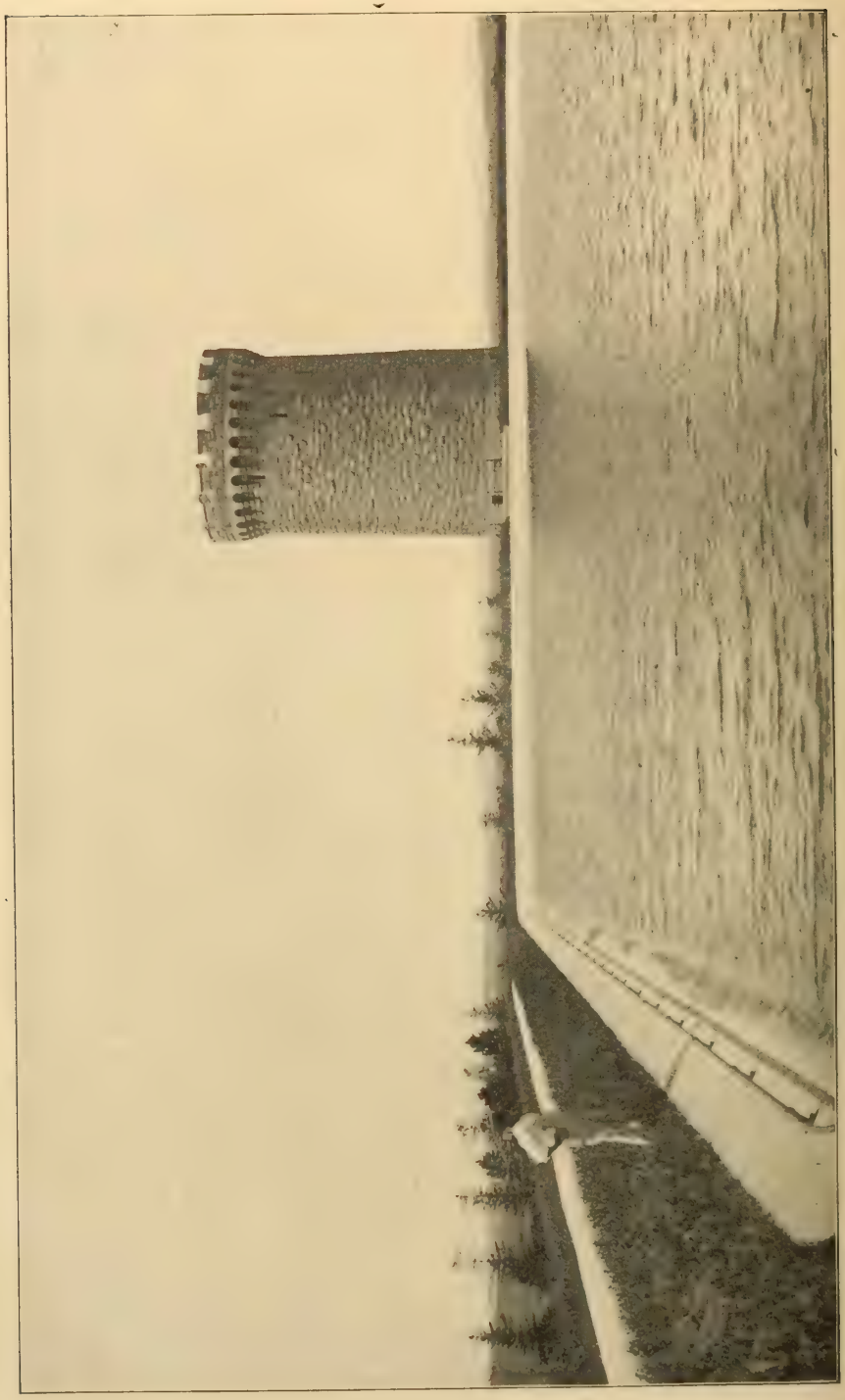
This reservoir is situated in the city of Quincy, and is used

for the storage of water to be used in case of accident to the pumping machinery or to the pipes leading from the pumping station at Chestnut Hill Reservoir ten miles distant. Water is stored and the pressure equalized for the ordinary use of the city in two standpipes in which the water is maintained at a level of about 50 feet above the high water level of the reservoir, so that it is only in cases of emergency that water is drawn from the reservoir. It is oblong in shape, 350 feet long and 150 feet wide at the top of the inner line of the embankment. The embankments are built of clayey hard-pan excavated from the reservoir, placed in 4-inch layers and thoroughly rolled. They are 17 feet wide at the top, with the inner slopes 1¾ horizontal to 1 vertical, and the outer slopes 2 horizontal to 1 vertical. The bottom and inner slopes of the reservoir are covered with concrete extending on the slope 2 feet vertical above high water. The concrete is in two layers between which there is one-half an inch of Portland cement plaster. On the bottom of the reservoir the lower layer is of natural hydraulic cement concrete 4 inches in thickness, the upper layer of Portland cement concrete also 4 inches in thickness. On the slopes both layers are made of Portland cement concrete, the lower layer being 6 inches thick, the upper layer 24 inches thick at the top and 5 inches thick from about one-third of the way down the slope to the bottom. Constructed in the embankment at the west end of the reservoir and entirely below the top of the embankment, there is a gate-chamber of concrete masonry containing pipes and valves for controlling the flow of water into and out of the reservoir. A granolithic walk, 6 feet in width, surrounds the reservoir at the top of the embankment.

Near the reservoir there is located a standpipe 30 feet in diameter, 64 feet 4 inches high, enclosed by a granite masonry tower 77 feet high, of pleasing architectural appearance, which acts as a protection against freezing of the water, and affords an observatory from which the public can enjoy extended views of the surrounding country.

Bear Hill Reservoir.

This reservoir is situated in the Middlesex Fells in the town



FORBES HILL RESERVOIR AND WATER TOWER.

of Stoneham, about 1,500 feet west of the northerly end of Spot Pond. It is 29 feet higher than the Fells Reservoir, and is now used for supplying water to the town of Stoneham. It was formed by constructing two dams of concrete masonry and earth across a depression in the rocky ridge which forms the summit of Bear Hill, thus enclosing an area of about three-fourths of an acre. The bottom of the reservoir is almost entirely rock in which there are numerous seams. These seams were very carefully plastered with cement mortar, and the whole bottom washed with Portland cement grout. The maximum depth of water in the reservoir is 15 feet. The concrete walls forming the dams are vertical on the water side from the bottom to a point 5 feet below high water mark, and above that point slope upward and outward with an incline of 1 to 1 to a height 2 feet above high water. The upper 5 feet of the slope is paved with stone, from the excavations, laid in cement mortar. A small chamber built of concrete masonry with a superstructure of granite, containing sluice gates for controlling the flow of water into and out of the reservoir, is located near the center of the north dam.

Waban Hill Reservoir.

This reservoir is located on Waban Hill in the city of Newton, about 7,900 feet from the high-service pumping station at Chestnut Hill, and is used in connection with the southern high-service of the Metropolitan District. It was built by the city of Newton in 1876, and purchased for the Metropolitan Water Works in 1900. It was constructed with earth embankments 14 feet wide at the top, having 1½ to 1 slopes on both inner and outer slopes, the inner slope being covered with granite paving 15 inches in thickness, bedded in 6 inches of broken stone, under which there is 24 inches of puddle made from the clayey gravel excavated on the reservoir site. The bottom of the reservoir is covered with 6 inches of concrete resting on 24 inches of puddle. The depth of water in the full reservoir is 16.7 feet, the high water elevation is 264.50 above Boston city base, and its capacity is 13,500,000 gallons.

Pipe Lines.

Water is distributed to the several cities and towns through 83.80 miles of pipes from 60 inches to 12 inches in diameter.

The lengths and sizes of the principal lines of pipe are as follows:

	Service.	Size (ins.)	Length (feet.)
Pumping station at Chestnut Hill to Spot Pond, two lines:	Low	60	6,432
West line	Low	48	46,660
	Low	*36	800
	Low	48	59,534
East line	Low	*36	5,160
Terminus of Weston Aqueduct to connection with two 48-inch mains at Chestnut Hill Reservoir	Low	60	2,626
	Low	48	36,800
	Low	48	7,220
Supplying low-service to Everett, Chelsea, East Boston and Charleston from 48-inch main in Malden	Low	42	8,044
	Low	30	280
	Low	24	6,500
	Low	20	1,910
Pumping Station at Chestnut Hill to Forbes Hill Reservoir, supplying Quincy, Milton and the higher portions of Boston:			
Pumping station to Forest Hills	So. high	48	18,339
Forest Hills to River Street	So. high	36	17,400
River Street to Forbes Hill Reservoir	So. high	24	15,620
Pumping Station at Chestnut Hill Reservoir to Waban Hill Reservoir, thence to Watertown and Belmont:			
Pumping Station to Waban Hill Reservoir	So. high	36	8,317
Waban Hill Reservoir to Watertown	So. high	20	12,704
Watertown to Belmont line	So. high	16	4,217
Pumping Station at Spot Pond to Fells Reservoir	No. high	36	4,785
Fells Reservoir to Malden, Medford, Somerville, Everett, Chelsea, Revere, Breed's Island, Swampscott and Nahant:			
Fells Reservoir to Elm Street, Malden	No. high	36	7,305
Elm Street, Malden, to Boston Avenue, Medford	No. high	20	15,282
Boston Avenue, Medford, to Cedar Street, Somerville	No. high	16	4,335
Elm Street, Malden, to Hancock and Cross Streets, Malden	No. high	30	7,289
Hancock and Cross Streets, Malden, to Broadway, Everett	No. high	24	4,319
Broadway, Everett, to Fenno Street, Revere	No. high	20	9,740
Fenno Street, Revere, to Beachmont, Revere	No. high	16	10,284
Beachmont, Revere, to Breed's Island	No. high	12	3,812
	No. high	20	113
Beach Street, Revere, to Nahant and Swampscott	No. high	16	30,425
	No. high	12	3,780
Fenno Street, to Revere Reservoir	No. high	12	865
Fenno Street to Chelsea Reservoir	No. high	16	2,528

	Service.	Size (ins.)	Length (feet.)
Spot Pond Pumping Station to Bear Hill Reservoir and Stoneham:			
Pumping Station to Main and South Streets, Stoneham	No. high	24	5,876
Main and South Streets to Bear Hill Reservoir	No. high	20	1,638
Main and South Streets to Stoneham	No. high	20	4,754
Mystic Reservoir to Walnut Street, Somerville, two lines:			
North line	Low	24	10,860
South line	Low	30	11,200
Mystic Reservoir to Arlington:			
Reservoir to Mystic River	Low	30	3,610
River Crossings	Low	36	566
Mystic River to Parkway	Low	24	3,269
Parkway to Pumping Station	Low	20	9,876

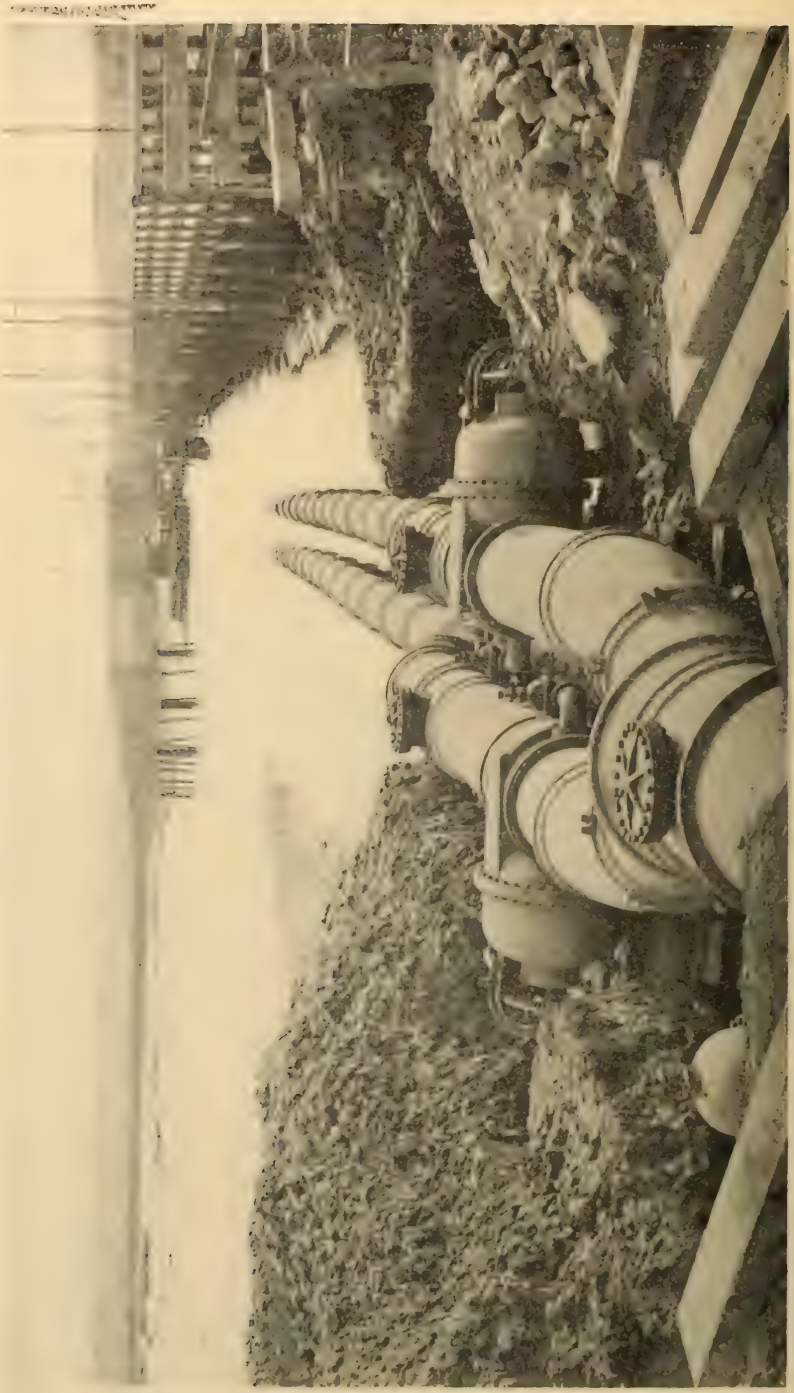
*At the crossing of the Charles River on the west line, and of the Charles, Mystic and Malden rivers on the east line, two parallel lines of 36-inch pipe are used in place of one line of 48-inch pipe.

Connected with these mains, there are 543 valves for controlling the flow of water and 53 Venturi meters of sizes varying from 6 to 48 inches, by means of which a continuous record is kept of the quantity of water used in each of the eighteen municipalities supplied with water.

With the exception of a 30-inch pipe-line, 11,200 feet long, between the Mystic Reservoir and Walnut Street, in Somerville, which is wrought iron, lined and covered with cement, and 39 feet of 36-inch wrought-iron pipe at a brook crossing, all of the distributing pipes belonging to the Metropolitan Works, are made of cast iron, and laid with leaded joints. The 36-inch pipes used in the crossing under the Charles, Mystic and Malden rivers, which are navigable streams, are 1.65 inches in thickness. In these pipe-lines, some of the joints are of the ordinary bell and spigot form, some have the spigots turned to a slight taper and forced into a leaded socket, and some have spherical spigots leaded into sockets, so as to make a flexible ball and socket joint.

The two lines of 24-inch pipe which pass under the Chelsea Creek between Chelsea and East Boston, have flexible leaded joints on each pipe. The line laid by the City of Boston in 1870 has joints which are flexible only in a vertical plan; those on the line laid in 1900 by the Metropolitan Water and Sewerage Board, have the Ward ball and socket joint.

The 24-inch pipe-line crossing the Mystic River between



THIRTY-SIX-INCH PIPES CROSSING MYSTIC RIVER.

Chelsea and Charlestown, is laid under the channel in a tunnel 6 feet in diameter and 145 feet long.

The distribution systems in the several cities and towns which are supplied with water from the Metropolitan works contain 1,447 miles of pipes, 147,794 service pipes, 13,492 fire hydrants and 17,976 water meters.

Measures Taken to Improve the Quality of the Water and to Prevent its Pollution.

In addition to the removal of soil from the bottom of the storage reservoirs, the measures taken to improve the quality of the water and to prevent its pollution are:

1st. The construction of ditches for the purpose of draining the swamps in the watersheds;

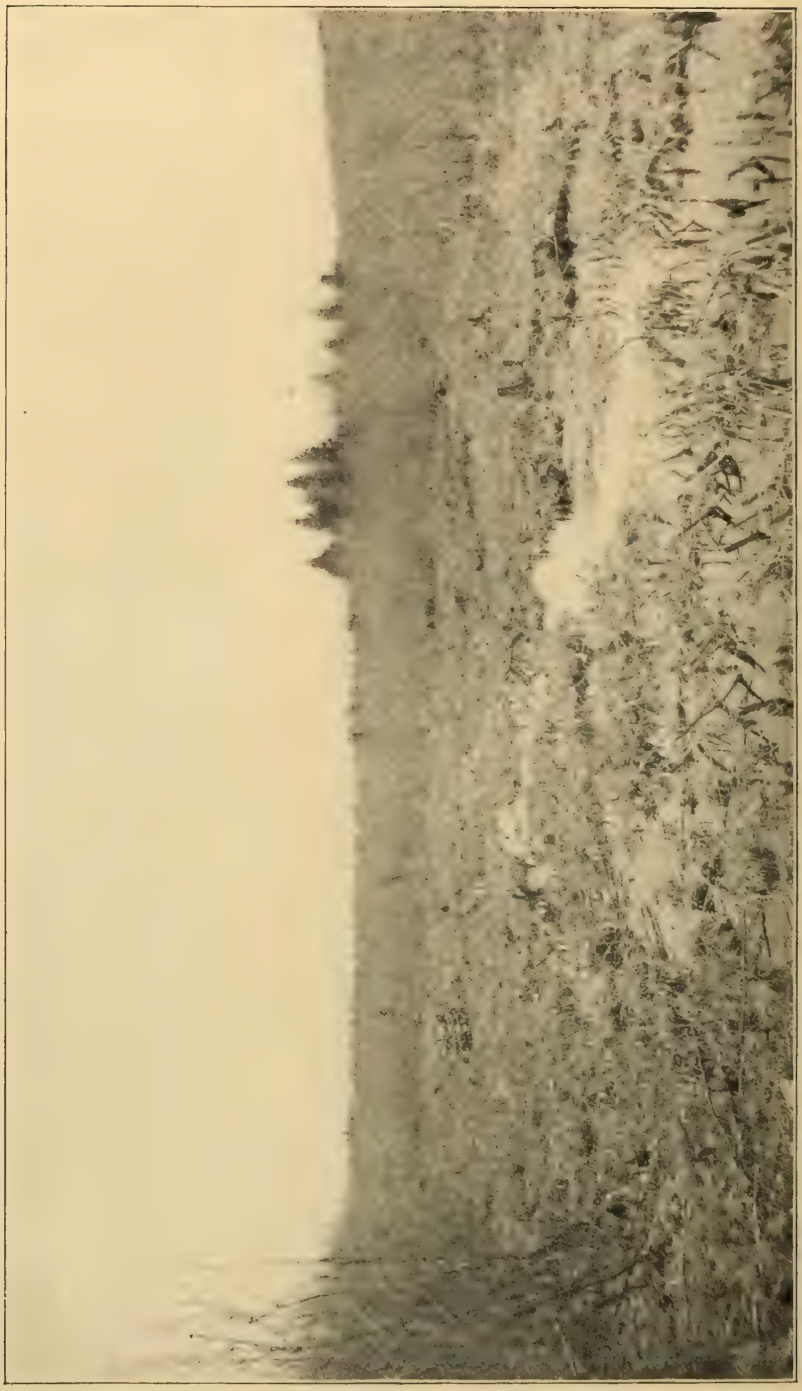
2d. The construction and maintenance of works for filtering water of objectionable quality before permitting it to enter the reservoirs;

3d. A constant and careful inspection of the watersheds for the purpose of elminating any possible sources of pollution.

Where the water passes through swamps it takes up organic matter and acquires a deep brownish color. For the purpose of preventing this several of the larger swamps have been drained by the construction of ditches generally placed near the edges of the swamps so as to intercept the water from the uplands and convey it to the reservoirs without deterioration.

On the Sudbury watershed swamps tributary to the open channel of the Wachusett Aqueduct, having an aggregate area of 667 acres, are drained by 15.55 miles of ditches, and other swamps draining into the Sudbury Reservoir and into Framingham Reservoir No. 3, having an area of 270 acres, are drained by 9 miles of ditches. On the Wachusett watershed 132 acres of swamp area are drained by 2.85 miles of ditches.

These ditches are of sufficient size to convey all water which is likely to reach them except during times of extremely high flow. They are constructed with a board bottom 12 inches wide, with triangular strips of wood 3 inches high on each side forming a footing for stone paving on the sides of the ditches which have slopes of 2 horizontal to 1 vertical. The depth of the ditches is generally from 1½ to 2½ feet.



SWAMP DRAINAGE—SWAMP BEFORE DRAINAGE.

SWAMP DRAINAGE—SWAMP AFTER DRAINAGE.

Residing on the areas which drain into the several reservoirs from which the water supply is drawn, there are the following populations:

POPULATION.

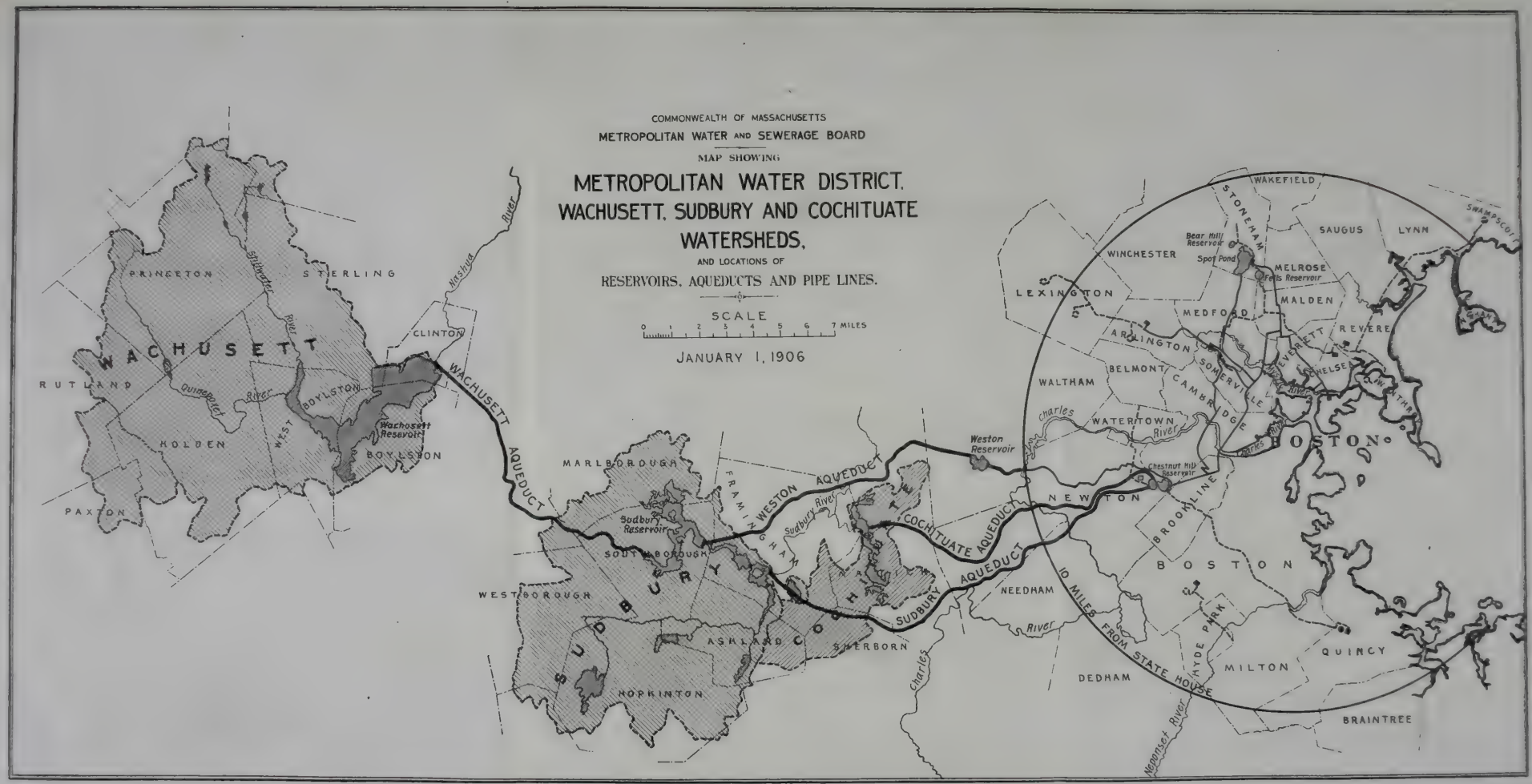
	Total.	In dwellings not connected with sewer.	Per sq. mile in dwellings not connected with sewer.
Wachusett watershed	5,772	5,772	49.
Sudbury watershed	21,131	10,575	140.6
Cochituate Watershed ...	15,508	6,521	328.7

The thickly settled portions of Westborough and Marlborough on the watershed of the Sudbury River, and of South Framingham and Natick on the watershed of Lake Cochituate, are provided with systems of sewerage by which the house drainage is carried outside the limits of the areas draining into the Metropolitan sources of supply.

Running through the thickly populated portions of the city of Marlborough and the town of Natick there are brooks which receive street washings and other surface drainage which it is undersirable to have run directly into water which is to be used for domestic purposes. Works have been constructed and are continuously operated for filtering the water of these brooks before admitting it into the reservoirs. The water of Marlborough Brook, which drains an area of about two square miles at the upper end of the Sudbury Reservoir, is filtered previous to its admission to the reservoir on twenty-four filter-beds having an aggregate area of 14 acres. The water flows from the brook by gravity onto the beds, and after passing through the sand or gravel is collected in under-drains and conveyed to the river.

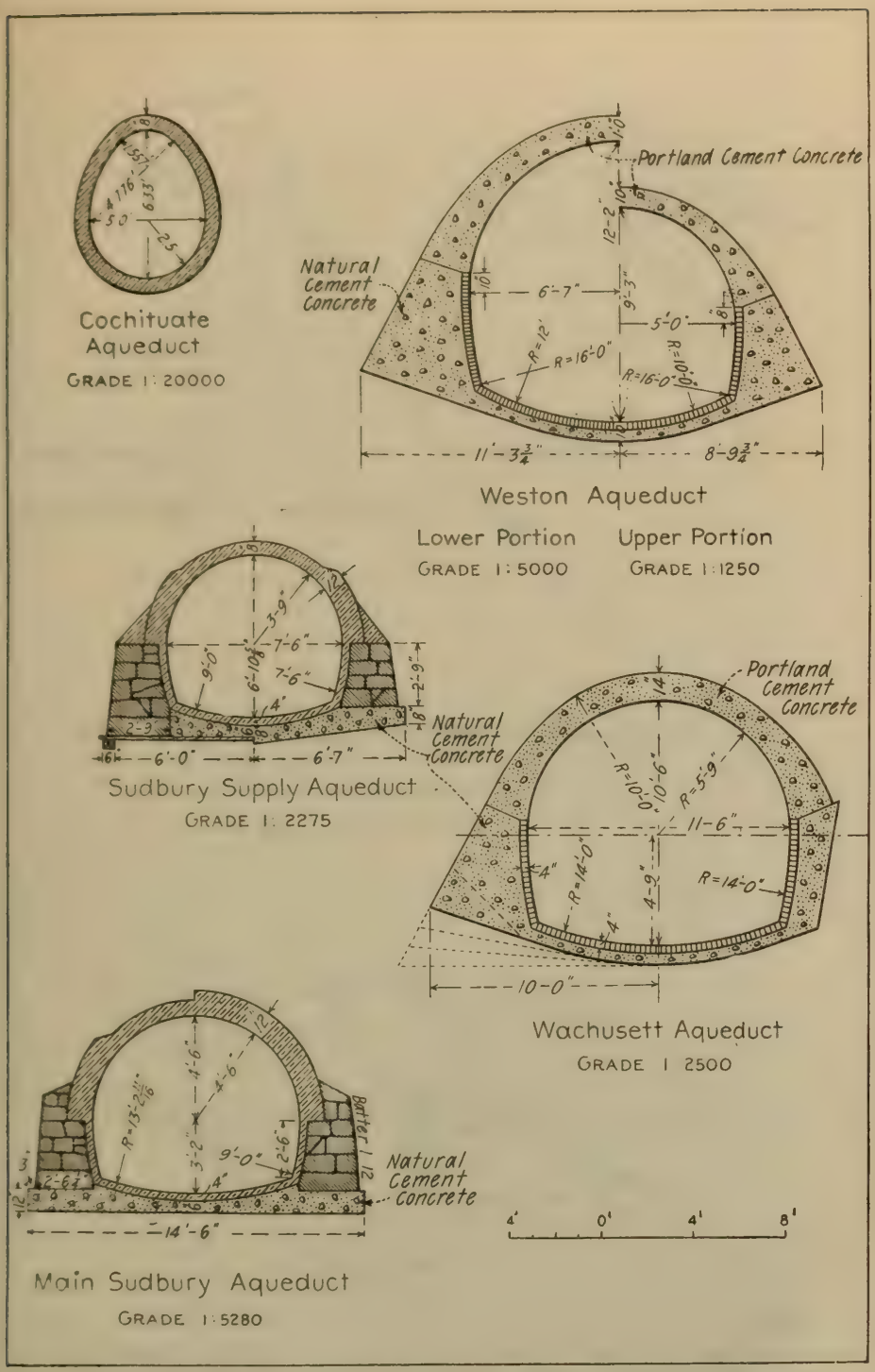
The water of Pegan Brook, which runs through the village of Natick and enters the south end of Lake Cochituate, is pumped on to five filter-beds having an aggregate area of 2.9 acres. The pumping machinery used consists of two Lawrence centrifugal pumps, one 8-inch and one 10-inch, directly connected to 5-inch by 10-inch by 7-inch vertical Cross compound engines of the marine type.

Chemical examinations of the water in the different reservoirs are made monthly by the State Board of Health, and



PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906.

METROPOLITAN WATER WORKS.



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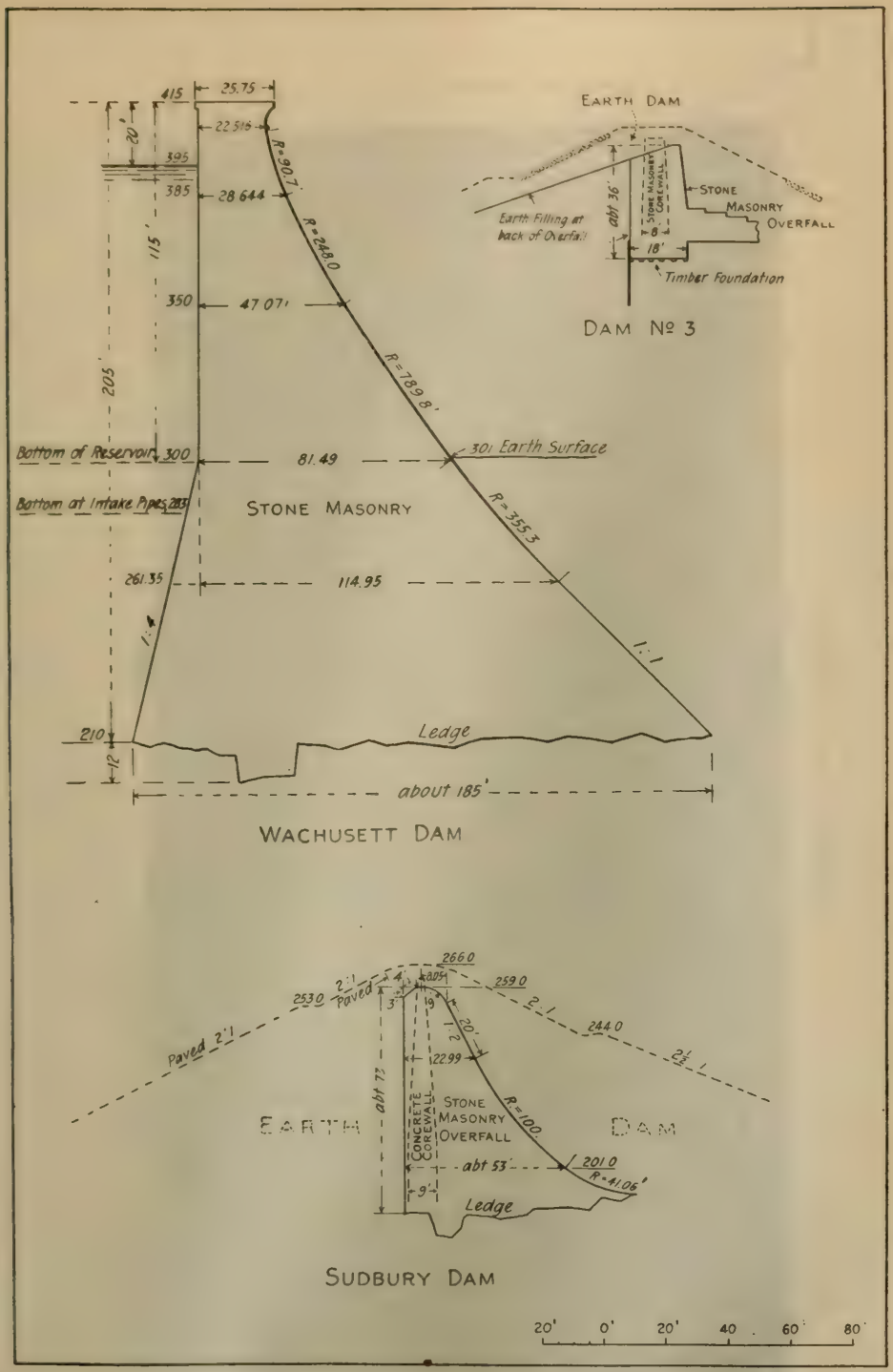

PROCEEDINGS AMERICAN WATER WORKS ASSOCIATION, 1906.

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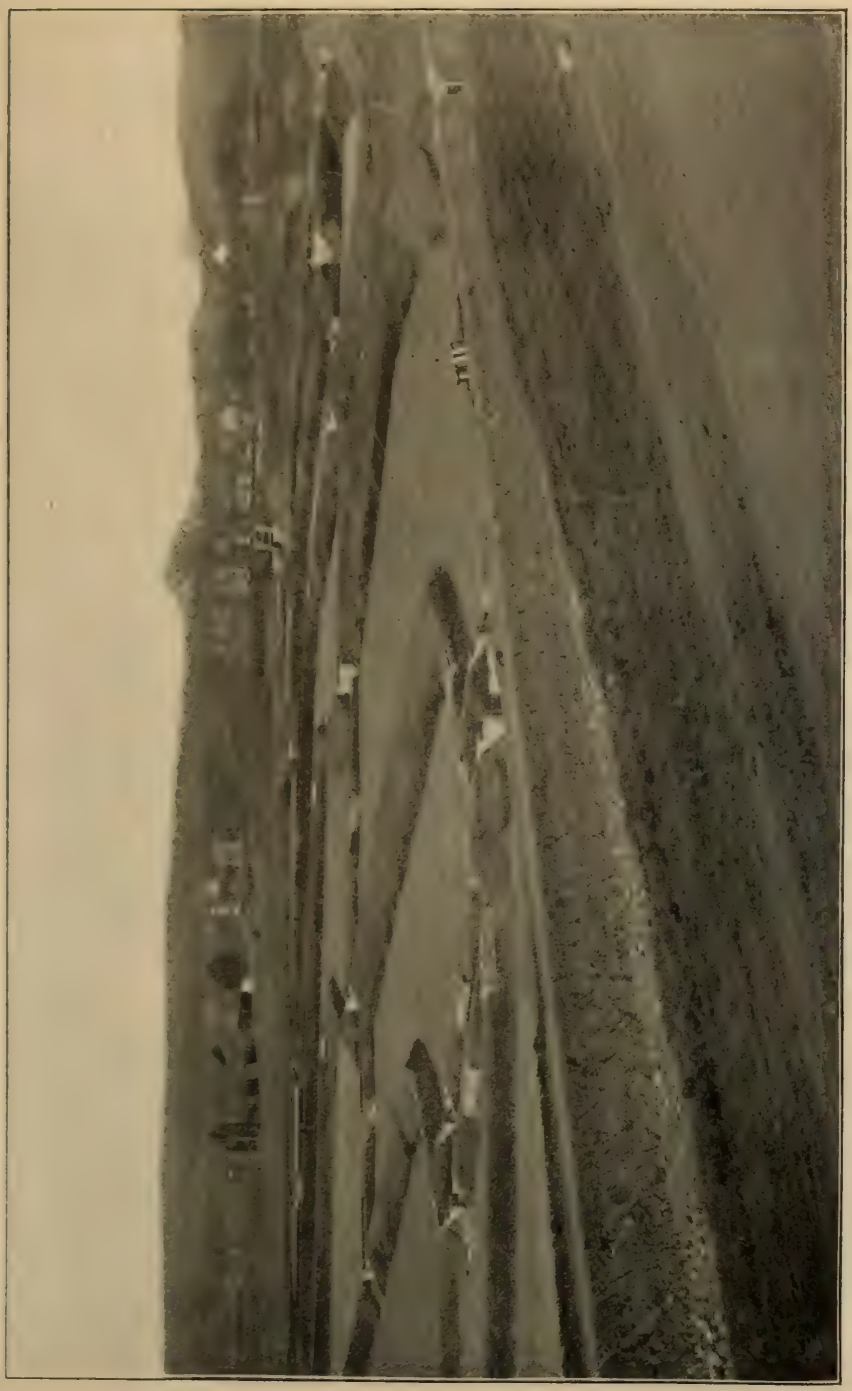


MARLBOROUGH BROOK FILTER BEDS.

observations of the color and odor of the water, and of the number and character of the organisms present, are made weekly in the laboratory of the Metropolitan Water and Sewerage Board.

Clinton Sewerage.

The town of Clinton, having a population in 1905 of 13,105, formerly discharged its sewage directly into the Nashua River at points below the site of the Wachusett Dam. The diversion of the water for the use of the Metropolitan Water Works reduced the quantity flowing down the river below the dam to such an extent that the direct discharge of sewage into the river would have caused an annoyance to the persons resident upon its banks. Provision was therefore made in the Metropolitan Water Act for the diversion of this sewage from the river, and disposal works have been built and are maintained by the Metropolitan Water and Sewerage Board.

An intercepting sewer composed of 3,661 feet of 20-inch and 853 feet of 24-inch vitrified pipe, and 1,120 feet of 30-inch brick sewer, conveys the sewage to a reservoir 100 feet in diameter, holding 600,000 gallons, from which it is raised 55 feet by means of a 3,000,000-gallon compound duplex pumping engine built by the George F. Blake Manufacturing Company, through 2,191 feet of 18-inch cast-iron pipe, and discharged intermittently upon twenty-five filter-beds having an aggregate area of 23.5 acres. From the underdrains of the beds the filtered water flows to the river. The daily average quantity of sewage treated in 1905 was 643,000 gallons.

Future Supply of the Metropolitan Water District.

The scheme recommended by the State Board of Health for furnishing an additional supply of water for the Metropolitan District was adopted not only on account of its adequacy for furnishing a large immediate addition to the supply, but also on account of the opportunities it afforded for supplying the needs of the future. Lying between the Sudbury and Nashua watersheds is the Assabet watershed with an estimated daily average capacity of 28,000,000 gallons. West of the Nashua watershed are the Ware and

Swift rivers with an estimated daily capacity of 271,000,000 gallons, which can be diverted into the Wachusett Reservoir by the construction of tunnels having an aggregate length of about 28 miles.

Upon the Swift River, there is a very favorable location for the construction of a storage reservoir, and a reservoir covering 30.9 square miles with a capacity of over 400,000,000,000 gallons can be made by two dams respectively 2,470 feet long and 144 feet high, above the river, and 2,065 feet long and 114 feet high.

The Assabet, Ware and Swift supplies, with the works already constructed, will provide a safe daily supply of 472,000,000 gallons, while further to the west are the Westfield and Deerfield rivers, capable of furnishing 500,000,000 gallons per day in addition, if required, in the distant future.

QUESTION BOX.

I. Is it possible for surface water to enter a water main through a leaky joint or other opening, when the main is under pressure? Would the principle of endesmose or exosmose apply in such a case?

SECRETARY DIVEN: As a matter of fact, I inserted that myself. I had a case where the State Board of Health made a report upon the plant of which I was in charge—not in South Carolina. It was stated that there was a large increase in bacteria between the intake and the filter plant, probably due to impurities in the soil leaking into the water main. The water main was under a pressure varying from 75 pounds to 30 pounds during its entire length. I paid very little attention to the matter, thinking that the man was probably a better politician than he was a chemist; but I heard since going to South Carolina a chemist insist upon the same thing. I was in hopes that some of our experts would take up that question, but they do not seem to have done so.

MR. WORRELL: My Company was up against a proposition like that several years ago when an ambitious young physician of our city (Selma, Ala.,) wished to advertise himself at our expense. He sought in various ways to get some kind of a "talking-point" against us, it being quite popular at that time to "jump on the Water Company" which was then being used as a local political football. With a wise and knowing look he stated to a crowd at a corner drug store, one evening, that outside impurities *could* get into water mains while said mains were under pressure and that it was easily explainable by the theory of osmosis, citing, as an illustration of the theory, that an unbroken egg might be placed in a dish of salt water and left there for several hours and upon being broken would be found to contain more or less salt in solution, hence that this would prove that a water main by this same "osmosis," even though it be under pressure, will absorb impurities from the soil, all of which no practical mind can believe. The person who asked the above question is respectfully referred to the definition of "Osmose" in the "Century Dictionary" from which he may gain further information as to the "theory" but impossibility of such a thing as this extraordinary diffusion.

SECRETARY DIVEN: I cannot believe that surface water will mix with the water in a main under pressure, even though there be a considerable leak in the main. My experience leads me to believe that the flow will be all out.

2. Is supplying water for power, operating elevators, motors, etc., a legitimate part of the business of a water department or company?

3. Where a 'flat rate' has been paid in advance, and a receipt given to a future date, has a water department or company a right to set a meter and charge for water at the meter rate before the expiration of the time for which advance payment has been made? Legal decisions on this question are desired.

SECRETARY DIVEN: That is a request for legal decisions somewhat on the lines of Mr. Sawyer's request for opinions on other things.

MR. ROSAMOND: I think that is largely a matter of conditions in the contract, if it be a water company, or if a water department, the city ordinances. However if it could be shown that water was being wasted the courts would sustain a water department, or company, in placing a meter on a service. On several occasions I have set meters on services where water was being wasted and in all cases the meters have remained on the services. The matter was at one time turned over to the city attorney in Ft. Smith, Ark., but after investigating it he failed to bring suit.

SECRETARY DIVEN: The letter enclosing this question stated that they had attempted it, and a contest was brought up by the consumer on the ground that he had a receipt for all water that he wanted to use until a certain time, and that they could not change his rate till that time had expired.

MR. REIMER: In New Jersey the law seems to uphold such a procedure, the requirement being that the proportion of the amount paid as a flat rate, represented by the unexpired portion of the flat rate period must be applied to the payment of the meter charges.

MR. ROSAMOND: I am quite certain that if past proceedings of this Association are referred to, decisions will be found quoted on that. I have seen them.

MR. KEELER: I have had a similar experience in the State of Illinois. In the case of parties who had paid a flat rate and abused their privilege, we put a meter on and gave them credit for a proportional amount for the time that had not expired, and then put them on a meter basis. That is the law in Illinois, and it is equity and justice; and we enforce it.

4. Can water companies or departments legally collect water rates in advance? Legal decisions are requested on this question.

SECRETARY DIVEN: I think that was taken up by Mr. Gwinn at one time.

MR. ROSAMOND: The questioner fails to state whether the service is being abused, or water wasted; in either case a rule requiring a meter on a service would be a reasonable one, and I have no doubt but that the courts would sustain a water company, or department in enforcing such a rule. In a case of Harbison *vs.* Knoxville Water Company, 53 S. W. 993, the court held: That a public water company is a quasi public corporation.

MR. VEACH: Does not that depend upon how your contract or ordinance reads?

MR. REIMER: Mr. Gedney, City Counsel of East Orange, N. J., a member of this Association, states that in New Jersey the law and the court decisions uphold the practice mentioned. It is entirely legal to collect water rates in advance and also to collect interest on such charges as are not paid in advance.

MR. F. L. FULLER: I think here in Massachusetts it is very common, perhaps almost universal, to charge in advance; but if a man only uses water for a portion of the year he gets a rebate; so that he is squared up. He simply pays in advance with the idea that if he does not use the water for the full period a proportional amount will be refunded to him.

5. What degree of hardness or alkalinity must a water have to make the use of lead service pipes safe?

MR. C. A. BROWN: I think that question ought to be more definite. There are several kinds of hardness in water. With the work that is being done throughout the country with lime as an agent for purification a question has already arisen at one or two points regarding caustic lime, which occasionally

appears in the water; and I think that that question can be subdivided into two or more questions, which would bring out the definite action of the caustics—the normal carbonate and the bi-carbonates of lime.

6. I would like to ask through the Question Box if any of the members of the American Water Works Association have had experience with joint action on their water mains, as a result of electricity from street car rails? I presume this matter has been thrashed out in this Association, but I have not happened to see the results of such discussion. I have made diligent inquiry around Boston, and have not found a sample of genuine joint action, though there is a good deal of trouble from electrolysis.

SECRETARY DIVEN: I presume the question means whether electrolytic action is more common near the joints than at other portions of pipes. I think that might be referred to the Committee on Electrolysis.

7. I would like also to ask if any one in these days favors the so-called "drainage system" of removing electricity from water mains—I mean anybody except the street railway officials. They do, I know, for they advised it in a case I know of this very year.

SECRETARY DIVEN: I fancy that that refers to bonding of the rails and the pipes; I don't know what else. I think that would better go to the Committee on Electrolysis also.

MR. LORD: I would like to ask a question as a little matter of information that we want in our town. Our pumping plant is a combination water power system; about eight months in the year we have water power to drive our power pump; the remaining four months we have to use a steam pump auxiliary. We have an electric power line running by our pumping station which has plenty of reserve, and it has occurred to us that perhaps when our water power is failing that we might, by the use of an electric motor in connection with our water wheels, drive our power pump for the six or eight weeks when the water power is barely sufficient for domestic purposes. This would obviate the necessity of getting up steam, getting our engineers, and running a steam plant. I have no doubt that later on this question will be submitted to Mr. Hague,

or some of the other experts; but I would like to know if any of the other members here know of a combination for water power pumping with electricity in order that we might correspond with the people running it and get information in advance of what our expert would tell us. It is a direct pumping system that we are on. We have to have two speeds; one for domestic pumping, and one for fire. I would like to ask if any mmbers of this Association know of such a plant?

A MEMBER: I would refer Mr. Lord to the electric companies. They can give that information.

MR. LORD: We have had engineers from the General Electric, and also the Westinghouse people, but they do not seem to want to tackle the proposition. If we were pumping to a reservoir so we could put a motor on at constant speed, there would be no difficulty; but we are pumping direct without a reservoir or stand pipe, and we have to have two speeds. It either means the combination of shafting and gears, or a variable speed motor. We have no storage. We pump direct.

PROCCEDINGS
of the
TWENTY-SIXTH ANNUAL CONVENTION
of the
AMERICAN WATER WORKS ASSOCIATION,
held at
Boston, Mass., July 10, 11, 12, 13 and 14, 1906.

FIRST DAY—MORNING SESSION.

Tuesday, July 10, 1906.

Mr. J. A. Tilden, the Chairman of the local Committee of Arrangements, called the Convention to order, and said:

MR. PRESIDENT, LADIES AND GENTLEMEN, MEMBERS, ASSOCIATE MEMBERS AND GUESTS OF THE AMERICAN WATER WORKS ASSOCIATION:

Following a time-honored tradition, it falls to the lot of the Chairman of the local committee to welcome you to the place of meeting. Unfortunately the Chairman is not the creature of his own appointment; he is the victim of an accident—the accident being due to our worthy President.

Your Chairman finds that he is neither golden of thought nor silver of speech, and is consequently entirely unable to do justice to the occasion. So that in the absence of any particular qualifications in that line he has undertaken to welcome you through parties who I am sure will do full justice to the occasion.

In the first place, you are guests of this grand old Commonwealth of Massachusetts, and it would seem quite fitting that the State should say the first words of welcome. While we are not fortunate in having with us to-day His Excellency, the Governor, on account of his being unavoidably detained elsewhere, we are nevertheless fortunate in having the State represented by one whom you may be quite sure is safely "keeping the lid down," and one who, if the procession is orderly—as it generally is in the State of Massachusetts—will in due course be our Governor.

It gives me great pleasure, therefore, to introduce to you His Honor the Lieutenant-Governor, Eben S. Draper.

ADDRESS OF WELCOME BY HONORABLE EBEN S. DRAPER,

LIEUTENANT-GOVERNOR OF MASSACHUSETTS.

MR. PRESIDENT, LADIES, AND MEMBERS OF THE AMERICAN WATER WORKS ASSOCIATION:

I was very glad that the opening speaker referred to my one pre-eminent qualification, one in which I resemble Secretary Taft—the ability to "keep the lid down." While I do not weigh three hundred and fifty, still I am large enough to serve very well in that capacity.

I was very sorry that His Excellency, the Governor, was unable to be here this morning to welcome you to our State, but circumstances over which he had absolutely no control required his presence away from here, and it was impossible for him to come. He asked me to come and to say to you how sorry he was that he could not be here, and asked me to discharge as well as I could the duty which you had invited him to perform.

I can imagine no better State in the Union for a convention of this kind than the State of Massachusetts. We have many gatherings here of societies of different kinds; and when most of them come we have to admit that we are not able to produce from our soil many of the things that grow in other States; but when it comes to the production of water I think we are quite as well off as any other States in the country, unless it be New Jersey and Maine. (Applause.) In any event we are sure that the water we have here is good, and that you can get it even after midnight—and that is more than you can do with some of the things you find here.

Another thing that makes it peculiarly appropriate for gentlemen like you to meet in this city is that it is connected with education. While the State of Massachusetts is not great in agriculture, she is great in education, and especially so in technical education; and you are now holding your convention in the very heart and centre of technical training.

I remember very well, a good many years ago, bumping my head against various corners of this building and trying to learn something about abstruse mathematics and various other

topics that have to do with a technical education. There is no man in the State that has any higher appreciation of the Massachusetts Institute of Technology than have I; and I am very glad to say that in my opinion there is no institution in the world which stands better or higher than does this to-day. So it is peculiarly appropriate that gentlemen like you, who are interested in technical education, who have learned so much from it, and are so familiar with it, should meet here in Boston for an annual gathering of this kind.

Massachusetts welcomes all sorts and conditions of people within her borders, and is glad to have them here; but no set of men can come to Massachusetts whom she welcomes more gladly than she does those men who have accomplished things in the line in which she is especially interested.

I am sure that you will all enjoy very much an inspection of our Metropolitan Water System; and if it impresses you as much as it does me, I am very certain you will be glad to have an opportunity to look it over.

We are all very glad that you are within the borders of our State as our guests, and I know that the representatives of your Association who belong to us will extend to you the hospitality which you deserve. I trust that you may have a good time both in and out of your sessions here, and that your deliberations may be of great benefit not only to you but to the State and country.

I am very glad to have had the opportunity of being here. (Applause.)

Mr. Tilden: Logically the next speaker in order would be His Honor, Mayor Fitzgerald. I am expecting him here every moment, and in due course, when he shall have arrived, we will hear from him; but in the meantime you are not to forget that we are most immediately the guests of the Massachusetts Institute of Technology. Through their courtesy we are enjoying here unequalled facilities for convention purposes. We have this most beautiful hall, which is well lighted and ventilated and possesses excellent acoustic properties, and where every convenience for the convention is supplied. Below you will notice the facilities which we have been able to afford exhibitors, and also the large room for headquarters;

for all of which I am sure that every one of us feels a debt of gratitude to the Institute.

I had hoped very much to have had here with us to-day Dr. Henry S. Pritchett, President of the Institute, but he is also unavoidably absent.

(At this stage of the proceedings Mayor Fitzgerald arrived, and was greeted by the speaker, who then resumed his remarks.)

His Honor wishes me to proceed on the same lines that I was doing. As I was just saying, we are unable to enjoy the presence of Dr. Pritchett this morning; but as I said in the case of the Governor, we have another and an able representative. It so happens that the gentleman whom I am to introduce to you to speak on behalf of the Institute, and who is its professor of chemistry and bacteriology, is also President of the New England Water Works Association; so that he will be able to speak to you in a double capacity. In fact I want to say that it is through the kindness and through the efforts of Professor Sedgwick that we were enabled to get these quarters.

There is one thing that I would like to say in relation to Professor Sedgwick. He is one of those men who find all sorts and kinds of funny things in water; in fact he has educated us up in the New England Water Works Association to believe that the article is hardly fit to drink. That is why we have provided on Thursday evening something that looks rather doubtful but is really the most innocent thing you ever heard of. It is designated as "a stag entertainment." I have consulted very carefully with Mrs. Tilden in the matter, and she assures me it is quite harmless, that all of you good ladies can let your husbands go there while you go to the theatre; we at the "stag" won't have a drop of water to drink, because Professor Sedgwick says it is full of all kinds of things that are very dangerous to health.

I now have the honor to introduce to you Professor Sedgwick.

Address of Welcome by

WILLIAM T. SEDGWICK,

Professor of Biology and Lecturer on Sanitary Science and Public Health in the Massachusetts Institute of Technology and President of the New England Water Works Association.

Mr. President, Ladies and Gentlemen:

I too am very sorry that President Pritchett is unable to be here this morning to welcome you to the halls of the Institute of Technology. There was, of course, no difficulty in securing an invitation for a national association like this to meet within the halls of a great technical college. Any other place of meeting would, it seems to me, have been inappropriate, and we rejoice that in the absence of the students who usually fill these halls—I might say the young students—we have the more elderly students of water works from all over the country.

You are very welcome within our walls and we only hope that some of you will take occasion to look into our school. To be sure it is not running now, except in summer form, but you can get a good deal of information by simply asking at the office on the floor below.

If any of you want to see any particular thing we shall rejoice to show it to you. A number of our own faculty are among your members, and we shall be very happy to have you get out of us all that you can while you are here. The Institute includes now about 1,500 students in technical science, many of whom, of course, are interested in water-power and water supplies, and in water works in other ways; for there are two great lines, as you know and I know, in which water plays an important part in modern civilization, one by the energy which it carries, which it has got from the sunshine by which it is lifted into the air and put upon the hill-tops for our use as power, and another, of equal importance, in which it serves as part of the food of man; to do the work and be the servant of man, and to make a part of his food. Water is considered from both of these aspects in a modern technical school, of

which I am glad to say, we have more than one in Massachusetts. We have this and the Worcester Polytechnic Institute—an admirable institution—and we have technical departments in some of our colleges and universities. In all these technical schools water-power and water-supply are proper and natural subjects of study.

If we have any one little distinctive point just here, it is perhaps our unusual attention to the *quality* of water. As Mr. Tilden has intimated, we make here a special point of sanitary science, the reason being that Massachusetts is, to a remarkable extent, a state of cities. We have a great concentration of population in this very neighborhood. You may not realize the fact, but I believe it to be true, that within fifty miles of where you now sit is a larger concentration of population than within fifty miles of any other city in the United States, excepting only New York; in other words, Massachusetts being a state of cities, and Providence and Worcester and Lowell and other large cities being near by, we have hereabouts an immense concentration of population. Thus it has come to pass that problems having to do with the wholesomeness of water as well as of water-power greatly concern us.

You do not need to be told that Massachusetts is foremost along the line of water power—a state that was the home of James B. Francis (now deceased), and which is still fortunate in being the home of Hiram F. Mills, these being two of the most distinguished hydraulic engineers of the world, and both of them, I am happy to say, members of the corporation, in their time, of the Massachusetts Institute of Technology.

You may not be equally well informed in regard to the sanitary side, but if you are you know that our State Board of Health is the great leader in the United States in studies on the quality of water and has been such for years. The rest of us are following along after it, as well as we can, and we have arranged just under this hall an Exhibit of Sanitary Science as we try to teach it here at the Institute. If any of you choose to visit this exhibit, as I hope you all will, you may find something to interest you. Besides, we have at this Institute of Technology one thing of which we do boast a

little bit; we have a sanitary research laboratory and sewage experiment station for the study of water and sewage, given to us by an anonymous donor, and located at 786 Albany Street. We should be very glad to receive there anyone who chooses to come, and we will make a point of being there, some of us, to-morrow afternoon at four o'clock to show it to visitors.

And, also, the special exhibit, under this hall, I think you may be interested to see. We have had a great deal of pleasure in preparing it for you, having first made it ready for the American Medical Association, which met here in Boston last month—some ten thousand physicians being in attendance. We esteem it of even greater importance, from our point of view, to water works men, and so we of the Institute of Technology have arranged this exhibit, which I hope you will all take some pleasure in visiting.

Ladies and Gentlemen, we wish you to make yourselves quite at home in this building, but this is only a small part of the Institute of Technology. The big building adjoining on your right is ours, and a large set of buildings behind Trinity Church. We shall be very happy to have you look them over whenever you choose, but, at any rate, make yourselves as comfortable here as you can. Our clerks in the office below will be very glad, I am sure, to answer all questions and to do everything that they can as respresenting the Institute of Technology.

And now, if you will allow me to change my role and for a moment to speak to you as President of the New England Water Works Association, I wish to extend to you a hearty and fraternal welcome to New England. The New England Water Works Association, although local in name, is not entirely local either in function or in membership. Many of you gentlemen from outside New England are members of our Association, and we are proud to have you; but still, for the most part, we are a local Association. Charity is said to begin at home, and we have believed that water works science also should begin at home, although like charity, it should not end there.

You have come to New England and into our territory, and we bid you a most cordial welcome. As members of the New

England Water Works Association we shall be happy to do for you anything that we can do; for we know something of your thoughts, your doings and your professional skill. We feel that we can think and commune with you in a common language, the language of water and water works, and we know that there are things hereabouts that will interest you.

We are proud, as the Lieutenant-Governor has said, of our Metropolitan water supply. We are proud of many of our smaller local supplies. Interesting experiments are being made in the Lawrence experiment station of the State Board of Health and at other places. All through New England there is intense interest in water power and water supply.

In New England we have made a great deal of progress in the improvement of our water supplies, but we do not feel that for this we are entitled to special credit. It is chiefly because we have had the problems pressing on us first, here in Massachusetts and in New England, that will soon arise everywhere. Because of our dense population we have had to do something, and if we have done more in some directions than has been done elsewhere it may be attributed partly to this fact. No doubt it is true also that more has been done elsewhere in some directions than has yet been done in New England.

We believe in our local Association, but we believe also in the National Association. We believe in taking the larger view. We would not tie ourselves down to our own little affairs. It is for this reason that you are twice welcome here to-day. We welcome you as brothers in the water works profession, as fellow craftsmen, fellow scientific men and fellow administrators; and like yourselves, we are proud that most of the management of our modern water works systems, both inside of New England and outside, has been honest and upright and free from "graft"; so that, in general, the municipal management of water works is to-day regarded as one of the principal examples of successful municipal administration. (Applause.)

Now, Gentlemen, let us keep up on this high professional plane. Let us keep the American Water Works Association and the New England Water Works Association hand in

hand, fighting for the best things—the most economical, the most scientific, and the most sanitary administration of the water works of this country.

The New England Association extends to you a sincere greeting and hopes that your meeting may be most successful. It receives you with open arms, and would have been glad to have taken charge of your whole meeting; but some of your Local Committee said, "No, we don't want that, we want to run the thing ourselves, we want to do it in our own way." They were our own members, most of them, and we saw the point. You want to come here and have your own meeting. In the language of the South you do not want to be "toted around" by the New England Water Works Association and shown the things that interest us merely; you want to see for yourselves. And so, while welcoming you as individuals and collectively, on this occasion, we are not tendering to you any special entertainment. We are giving you what is, perhaps, the highest form of hospitality, the privilege of being let alone, of doing exactly what you want to do; but we stand ready—let me make this clear—as members of the New England Water Works Association we stand more than ready, to help you in every possible way, as individuals or as small committees, or in any way that we can or that you may desire.

Mr. Tilden says that my teachings have almost converted him to total abstinence—from water—and if, unhappily, any of you should suffer similarly, let me commend to you as a sovereign balm, the solemn rites of that novel ceremonial which he has arranged for Thursday evening, under the mysterious name of a "stag" entertainment. There you will find many a horn and perchance a cloven foot, but not, I am sure, any forked tail.

Finally, brethren, if there is anything whatever that we can do for you pray let us know it. May your meeting be most successful, and may you all come again soon to New England and to Boston. (Applause.)

Mr. Tilden: It gives me pleasure now to introduce to you one who is foremost in the city of Boston, and particularly so since he adopted as his motto, and which he has since made

good, "a bigger, better and busier Boston." That motto is worthy of the public spirit which is ascribed to our Western and Southern friends. We are waking up here now with new life, and we are all trying to "make good."

Furthermore, this same gentleman, when he was elected to the highest office in the gift of the city, found time in his inaugural address to pay particular attention to the problem of a pure and sufficient water supply, and I am sure that on account you will be pleased to hear from him, and that he will be pleased to address you.

I have the honor now of presenting to you His Honor, John F. Fitzgerald, Mayor of the City of Boston.

ADDRESS OF WELCOME BY

THE HONORABLE JOHN F. FITZGERALD,

MAYOR OF THE CITY OF BOSTON.

MR. CHAIRMAN, MEMBERS OF THE AMERICAN WATER WORKS ASSOCIATION, LADIES AND GENTLEMEN:

I assure you that it affords me the sincerest pleasure to welcome you all here to our historic city of Boston. I think that everything that can be said about our city, Massachusetts and New England, has already been well said by His Honor, the Lieutenant-Governor of the Commonwealth, and by Professor Sedgwick, who made such a beautiful address here a few moments ago. While on the stage here, he suggested a thought to me that I perhaps may well amplify upon, and repeating a statement made to me the other day by a Civil Service Commissioner, and which is along the same line of thought, and indicates how well conducted our water supply system has been here in the city of Boston. It is a great many years ago since municipalities and towns first took over water systems. I presume there are even yet some misgivings, perhaps, by some people in the different cities and towns in regard to the ability of municipalities to conduct the affairs of water companies as honestly, as efficiently and as economically as private companies; yet to-day I believe that I am within the bounds of truth when I say that at least seventy-five per cent. of the capital invested in water works in this country is invested by mu-

nicipalities, and I have heard very little criticism indeed in these later days in regard to the ability of cities and towns to conduct water plants honestly, economically and efficiently.

But what I intended to say to supplement what Professor Sedgwick said is that I was in the State House the other day, in conference with the Board of Civil Service Commissioners, who were appointed by the Governor of the Commonwealth—and in order that you may understand the political situation here, I may say that the Civil Service Commissioners are appointed by the Republican Governor, while we here in Boston have enjoyed a Democratic administration practically all the time during the past thirty years, with occasional intermittent lapses from virtue. One result is that there is a very great scrutiny exercised by the Civil Service Commission over the city administration of Boston. Mr. Warren, Chairman of the Civil Service Commission, told me the other day that their examiner, who is paid by the State Board, after the most careful examination of the pay-rolls in the Boston Water Department, found it absolutely perfect, found that there were no politics entering into it, that its affairs were conducted honestly and efficiently, and that Boston had the best municipal operation of a water system of any city in the world. I know that, as persons interested in municipal water undertakings, you are very glad to learn that you have come to a city which has such an efficient, honest and economical administration of its water system.

I want to correct one statement that Professor Sedgwick made when he said that if we have a perfect system here, if we have done more in connection with perfecting our water works and rendering them efficient than other cities in the country, it has been due to the congestion of population. I do not quite agree with him in that statement, and I want to say that it is my opinion, ladies and gentlemen, that if we have a perfect water system, more economically and better administered than any other city in the country, it is because we have men of intelligence, character, honesty and public spirit, like Professor Sedgwick, leading the way and pointing to better things all the time. (Applause).

The chairman said a moment ago in his introduction that

when I was elected the Mayor of the city of Boston I promised to try to make the city a bigger, better and busier one, and to see if we could not imbue into this good old city of Boston some of the progressive spirit of our Western and Southern countrymen, which has brought them such unbounded prosperity. That is true.

But there is one thing here in New England which we can't improve upon, and that is the character of the men that New England has given to the world. That is the reason why, my friends, we think ourselves superior to any city in the country in the methods that we employ in taking care of sewage. That is the reason that we think ourselves superior to any city in the country, and even in the world, in the purity of our water supply—because we have been fortunate here in this part of the country in having men like Professor Sedgwick and President Pritchett, and President Eliot of Harvard College, and other men of like character, who have given their time, their advice and their public-spirited endeavor freely to the citizens of Boston and to the state of Massachusetts, and thus insured to us the highest character of public service enjoyed by any community in the United States.

I think it is only fair here in the Institute of Technology, where we have assembled to-day, to pay that tribute to the men connected with these institutions. I do not know what in the world we would do without the lectures which are constantly given by Professor Sedgwick and the men associated with him here in this building, who are thereby inculcating in the people a love of sanitary science, and disseminating throughout the community that knowledge which teaches men not only to take better care of themselves, but of their families, their homes and the community at large.

It is a fact that we utilize our water supply to a larger extent than I think any other city in the country. Our per capita consumption in Boston to-day is about 169 gallons per capita per citizen per day. Now, think of it! When the ordinary usage of water in Berlin, I think, and some of the larger cities of Europe does not amount to more than 30 gallons, we use 169 gallons per day. Of course that may be called extravagance. We built a water works supply system here about ten

years ago which cost us about $30,000,000. Boston paid eighty-two per cent. of that. I went before the Legislature last year in regard to the law enacted by the Commonwealth taxing Boston for its water supply on the basis of property valuation rather than consumption, and under the operation of which there was no inducement to use less water, because the bill was the same. This year the Legislature passed a law which permits Boston to be taxed on the basis of consumption as well as valuation; so that I think when the Water Works Convention meets here again—and I hope you will honor us with your deliberations soon again—you will find that the per capita consumption is reduced sensibly; but we are now using that amount of water.

I was glad to see that one of the subjects that is set apart for discussion here is electrolysis. I had a talk recently regarding that matter with the Water Commissioner of Boston. We are building a tunnel underneath Washington Street, and we were compelled to relay the water-pipes there because some of them were found in a condition of practical destruction owing to electrolysis. I think that public service companies, such as electric light, trolley, telephone, etc., ought to be compelled to pay the municipalities in cases where damage from electrolysis can be laid at their door. I think that is a proper subject of discussion by this Convention, because, with the tremendous increase in the use of electricity, it is apparent that from year to year the amount of destruction of water-pipes that is going on in all the large cities of the country must be tremendous, and must be a great tax upon municipalities—a tax that they ought not to bear. That is one of the subjects that I saw on the program that is to be up here for discussion, and I hope that some definite action will be taken by this Convention, and some recommendation made.

I do not know that I have anything further to say. I do not want to indulge in a long, tiresome speech here. Like the other speakers, I welcome you to the city of Boston, and trust that your days here will be filled with most pleasant incidents, and that you will not only enjoy this city of ours, but also the surrounding territory. I think that every visitor who comes within our gates goes away feeling that Boston has the best

suburban territory and most enjoyable scenery of any city in the country. As one of the attractions of our city I might say that you can ride from Dedham, which is about seven or eight miles outside, to Arlington, about nine miles north, for five cents. I do not think there is any other city in the country which will give you as long a ride through as beautiful scenery for as little money. I would suggest that if a trolley party could be organized you would see as beautiful a territory as one would want to greet the eye.

We have Harvard College and other educational institutions of a high class; we have a magnificent harbor. You are to see that. On Thursday you will be the guests of the city of Boston, down our harbor. I trust when you go home, that you will have had such a good time here that you will induce your Congressmen to be friendly, so that when Boston wants an appropriation we will have someone fighting for the appropriation in every section of the country, because they have seen its harbor. I have tried to follow out, as suggested by your Chairman, the idea of making this a busier Boston. If I can induce you to make your Congressmen friendly, I think the little excursion is going to bear fruitful results.

In conclusion, I think Boston was one of the first cities to establish a public water supply in this part of the country. Ours was established as far back as 1652. It is true that we were behind Philadelphia and some of the larger cities which in later years instituted water supplies, but when we got started we went ahead very fast.

We have splendid water power here in New England. It sets the wheels of industry going, and gives us the largest and best cotton mills in the world. We have also some of the greatest woolen mills in the world. We make more shoes in Massachusetts than in any other state in the country. We furnish the largest production of shoes manufactured in the United States. That we have been able to hold our superiority along these lines of manufacturing is due to a considerable extent to our water power.

As the other speakers have told you, we have utilized the advantages which Nature has afforded us here twenty-five miles from Boston in the watershed where we have instituted

what we think is the best system of water supply in the world. While I have no objection to your drinking other things, I hope you will drink all the Boston water you can get hold of while you are here, for it will do you good, and you will go away feeling that you want to come to Boston again.

We have a city not only full of historical associations and beautiful scenery, but you can drink our water here feeling that it is good, and that there are no possible bad effects from it. (Applause).

MR. TILDEN: The city of Boston has long been fortunate in having in its midst a Society of Civil Engineers. I say long, because the Boston Society of Civil Engineers is, I believe, one of the oldest, if not the very oldest, engineering organization in the country. It is even older than the American Society of Civil Engineers. It is a Society that is very highly prized by a great many of our water works people here, many of whom are to be found among its members. The Society has given a great deal of attention to problems relating to water in its conventions and meetings. You will find scattered all through its proceedings very valuable information relating thereto.

It, therefore, seemed to our Committee to be very fitting that we should ask the Boston Society of Civil Engineers to join in the welcome; so I have the pleasure of introducing to you to-day Mr. Frank W. Hodgdon, Chief Engineer of the Harbor and Land Commission, and who is the President of the Boston Society of Civil Engineers.

ADDRESS OF WELCOME BY
MR. FRANK W. HODGDON, C. E.,
PRESIDENT BOSTON SOCIETY OF CIVIL ENGINEERS.

MR. PRESIDENT, MEMBERS OF THE AMERICAN WATER WORKS ASSOCIATION, LADIES AND GENTLEMEN:

It gives me great pleasure in behalf of the Boston Society of Civil Engineers to welcome you here to-day. Our Society, as intimated by Mr. Tilden, desires to join in welcoming you to Boston and to New England. The Committee said that they did not desire to have us take any active part, but in view of the fact that many of our members have such intimate rela-

tions with the different water works constructed in this vicinity and other parts of the country, we desire to offer you any facilities which individual members can give, and if at any time you will call upon any of our members they will be very glad to show you what they have done and where the interesting things are located which you desire to see.

In view of the speeches that you have already heard, and of the work that you have planned out before you now, I will refrain from further remarks now and simply extend the welcome of our Society. (Applause).

MR. TILDEN: Ladies and gentlemen, he whom I shall now introduce to you needs no introduction—a gentleman who has the interests of the Association at heart, and who has done everything in his power to make this convention a grand success. When I shall have introduced him to you, the labor of the Local Committee will have been concluded, that is, so far as this morning's program is concerned.

I am sure that we are very glad indeed that we have been so splendidly honored to-day by the representatives of the State, of the city, and of these institutions.

I have now the honor and pleasure of presenting to you Mr. B. C. Adkins, Water Commissioner of the city of St. Louis, the President of this American Water Works Association, who will now take charge of your deliberations.

RESPONSE BY PRESIDENT ADKINS.

LADIES AND GENTLEMEN:

It gives me pleasure to-day, on behalf of the American Water Works Assocaition, to respond to the most cordial words of welcome from the honored Sirs who have just spoken.

Boston, like other large cities, has its beauty spots where breathe forth their delicate fragrance, and its sun spots, where multitudes gather to enjoy Nature in its fullest sense; it has its beautiful driveways and its boulevards; its beautiful residences and its buildings; but withal when one has participated in all its beauties, there is one thing that we seek—pure, wholesome and refreshing water. To furnish this is our mission. It is indeed gratifying to the members of this Association to have this hand of welcome extended to them in the different cities

in which they have assembled, and especially so in your great city of Boston. Such welcome as has been accorded us to-day not only verifies the opinion in which your beloved city has been held by our members, but it acts as an incentive to the members to perform the mission which has been assigned to them—a mission of most vital importance to communities.

Although not stated, I suppose it is to be taken for granted that the Honorable Mayor has deposited the keys to the city in the hands of our Committee. On behalf of the members of this Association, I have the honor and the pleasure to extend to you and yours a most cordial invitation to attend the meetings of this Association, which promises to be the greatest in its history, not only from the point of attendance, but in the point of the papers to be presented, which I can assure you will be instructive as well as entertaining.

I thank you.

The following applications for membership were received and reported favorably upon by the Executive Committee, and the applicants were duly elected to membership:

For Individual Active Membership.

Allin, Thomas D., Civil Engineer, 101 East Walnut Street, Pasadena, Cal.

Baker, Horace S., Engineer of Water Pipe Extension, Room 317, City Hall, Chicago, Ill.

Barbour, Frank A., Hydraulic and Sanitary Engineer, 1120 Tremont Building, Boston, Mass.

Bartow, Edward, Director State Water Survey, University of Illinois, Urbana, Ill.

Bassett, Carroll P., C. E., Treasurer Commonwealth Water and Light Company, Summit, N. J.

Belcher, Donald M., Sanitary Engineer, 14 Prospect Street, Winchester, Mass.

Blake, C. H. M., Consulting Hydraulic and Sanitary Engineer, Apartado postal 94, Guadalajara, Mexico.

Blake, Edmund M., Civil Engineer, 8 Beacon Street, Boston, Mass.

Blossom, Francis, Engineer and Contractor, 52 William Street, New York, N. Y.

Bolton, Channing M., Chief Engineer Water Works, Charlottesville, Va.

Bowker, Charles L., Superintendent Brunswick and Topsham Water District, Brunswick, Me.

Brackett, Dexter, Engineer, Sudbury and Metropolitan Water-Works, Distribution Depts., 1 Ashburton Pl., Boston, Mass.

Bunker, George Cyrus, Chemist and Biologist, Littleton, N. H.

Burton, Henry, Superintendent and Chief Engineer Water Works, Port Huron, Mich.

Bush, John C., Superintendent of Meters, 541 Chenango Street, Binghamton, N. Y.

Caldwell, James H., Civil Engineer, 55 First Street, Troy, N. Y.

Carter, C. D., Superintendent Water and Sewerage, Charlottesville, Va.

Chisolm, Edward North, Jr., City Engineer and Superintendent of Water Works, Columbia, S. C.

Clark, Albert, Superintendent of Water Works, Bellingham, Wash.

Conlon, Thomas, Superintendent Water Department, Tucson, Ariz.

Cook, John H., Hydraulic Engineer, East Jersey Water Company, 158 Ellison Street, Paterson, N. J.

Crowther, Henry, Mechanical Engineer, 400 Chestnut Street, Philadelphia, Penn.

Cullinane, J. R., Manager West St. Louis Water and Light Company, St. Louis, Mo.

Dearborn, H. M., Superintendent City Water Works, Fernandina, Fla.

Deignan, John E., Asst. Eng., Dept. Water Supply New York City, 11 Winthrop Terrace, East Orange, N. J.

Downes, John R., Chemist and Bacteriologist Water Department, Box L., Filter Plant, Harrisburg, Penn.

Driscoll, Martin A., President Haverstraw Water Supply Company, Haverstraw, N. Y.

Eley, Frank, Water Purveyor, 460 Avenue E, Bayonne, N. J.

Fewell, J. H., Superintenden Light, Heat and Water Company, Jackson, Miss.

Folwell, A. Prescott, Editor *"Municipal Journal and Engineer,"* Flat Iron Building, New York, N. Y.

Foss, William E., Division Engineer, Metropolitan Water Works, Boston, Mass.

French, Arthur N., Superintendent Hyde Park Water Company, Hyde Park, Mass.

French, E. V., Mechanical Engineer, 31 Milk Street, Boston, Mass.

Fuertes, James H., Consulting Engineer for Hydraulic and Sanitary Works, 444 East 17th Street, Brooklyn, N. Y.

Fuller, Frank L., Civil Engineer, 12 Pearl Street, Boston, Mass.

Giesler, Arthur, Consulting Engineer, 29 Broadway, New York, N. Y.

Gray, H. S., Registrar Water Works, Minneapolis, Minn.

Gregory, John Herbert, Eng. in Charge Imp. Water & Sewage Wks., 506 American Savings Bank Bldg., Columbus, O.

Harrison, Edlow Wingate, Civil Engineer, 15 Exchange Place, Jersey City, N. J.

Hatch, Edward L., Assistant Treasurer Stamford Water Company, Stamford, Conn.

Hayden, N. W., President Windsor Water Company, Windsor, Conn.

Hazelhurst, J. N., Consulting Engineer, Mobile, Ala.

Hewitt, Thomas, Superintendent Water Works, Kingston, Ont.

High, S. Y., M. E., Superintendent Water Works, 6515 Indp. Avenue, Kansas City, Mo.

Hillabrandt, Lucian, Superintendent Water Works, Johnstown, N. Y.

Hines, Frank L., Superintendent Water Department, Salt Lake City, Utah.

Hodgson, John S., Wellington, Mass.

Holmes, A. G., P. O. Box 252, East Pittsburg, Penn.

Hunter, T. B., Resident Engineer, M. C. W. W., Monterey, Cal.

Jewell, Wm. M., Chemical and Consulting Engineer, Cable Building, Chicago, Ill.

Jones, Burk, Superintendent Water Works, Hattiesburg, Miss.

Kinnicutt, Leonard P., Director Department of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

Klingberg, W., Civil Engineer, Kingston, N. Y.

Latta, L. M., General Manager Akron Water Works Co., Akron, Ohio.

Lawton, R. W., Manager Jewell Export Filter Co. for India, 10 Clive Street, Calcutta, India.

Levering, W. A., Superintendent W. P. Extension, 317 City Hall, Chicago, Ill.

Litterer, Fred, Chief Engineer, 20 North Union Street, Decatur, Ill.

Lochridge, Elbert E., Engineer Springfield Water Department, 53 Bridge Street, Springfield, Mass.

Loetzer, C. E., Superintendent Sayre Water Co., Sayre, Pa.

Loomis, E. L., Superintendent Valparaiso Home Water Co., Valparaiso, Ind.

MacGonigle, Dr. John N., Superintendent Water Works Miami and Palm Beach, Miami, Fla.

McDargh, Harry J., Civil and Hydraulic Engineer, Maintenance Department, 1205 Conover Building, Dayton, O.

Mercer, E. A., Supt. Water Works, West Chester, Pa.

Merrill, Andrew S., Superintendent Bath Division of Maine Water Co., Bath, Me.

Merritt, D. S., Engineer and Superintendent Board of Water Commissioners, Tarrytown, N. Y.

Mixer, Chas. A., Engineer Light and Water Co., Rumford Falls, Me.

Monford, Wilson F., Chemist, Water Works, 77 May Street, St. Louis, Mo.

Monroe, H. G., Superintendent Water Works, Pontiac, Mich.

Moore, John M., Civil Engineer, Engineer and Superintendent, London, Ont.

Murphy, Howard, Civil, Hydraulic and Sanitary Engineer, 260 S. Third Street, Philadelphia, Pa.

Phillips, Geo. H., Commissioner of Board of Streets and Water Newark, N. J.

Potts, Clyde, Civil and Sanitary Engineer, 17 Battery Place, New York, N. Y.

Powell, Shepard T., Water Analyst, 31 Burdette Avenue, Troy, N. Y.

Prince, Edward, Consulting Engineer, 304 Sixth Avenue N,, Quincy, Ill.

Prince, Geo. T., The Denver Union Water Co., Denver, Colo.

Reagan, John F., General Manager Consolidated Water Co., Utica, N. Y.

Rohrbach, Wm. R., Manager Sunbury Water Co., Sunbury, Pa.

Ross, Charles H.; Superintendent Waterloo Water Co., Waterloo, Seneca County, N. Y.

Rutledge, Geo. H., Superintendent Water and Light Co., Concord, N. C.

Salmon, Frederick William, Civil and Mechanical Engineer, 127 S. Central Avenue, Burlington, Ia.

Schulz, C. F., First Assistant Engineer Cleveland Water Works, 6002 Clinton Avenue, Cleveland, O.

Schwertfeger, Wm., Secretary City Water Board, Wheeling, W. Va.

Sears, Walter, Chief Engineer Aqueduct Commission, 280 Broadway, New York, N. Y.

Senior, Samuel Palmer, Engineer and Superintendent Bridgeport Hydraulic Co., Bridgeport, Conn.

Shaw, Benj. T., Water Commissioner, Wilmington, Del.

Shaw, Walter A., Engineer in charge Chicago Water Works, 941 Fannell Avenue, Chicago, Ill.

Sluyter, E. W., Superintendent Water Works, Herkimer, N. Y.

Smith, W. T., Water Commissioner, DuBois, Pa.

Snell, George H., Water Commissioner and Superintendent, Attleboro, Mass.

Staples, George T., Superintendent Water Works, 64 School Street, Dedham, Mass.

Taylor, John T., General Manager Water Works, Beaver Falls, Pa.

Thomsen, Carl M., Water Works Superintendent, Farmington, Mo.

Townsend, E. R., Hydraulic Engineer, 125 Monroe Street, Chicago, Ill.

Tuttle, Arthur S., Principal Assistant Engineer Board of Estimate and Apportionment, 277 Broadway, New York, N. Y.

Van Gilder, L., Engineer and Superintendent Water Department, City Hall, Atlantic City, N. J.

Wagner, E. C., Superintendent Girardville Water Co., Girardville, Pa.

Wasteneys, Hardolph, Chemist Brisbane Board of Water Works, Brisbane, Queensland, Australia.

Weddle, Nelson, Jr., Secretary Water Co., West Newton, Pa.

Williams, Gardner S., Consulting Engineer and Professor Civil, Hydraulic and Sanitary Engineering, University of Michigan, 207 New Engineering Bldg., Ann Harbor, Mich.

Williams, Pat H., Supt. Water Works, Charlotte, N. C.

Witherell, Frederick W., Assistant Engineer, Penna. Dept. of Health, Room 168, State Capitol, Harrisburg, Pa.

Young, T. L., Superintendent S. S. W. W. Co., Chester, W. Va.

For Corporate Active Membership.

Campbell, J. A., Superintendent and Secretary Ocala Water Co., Ocala, Fla.

Cole, W. W., General Manager Elmira Water, Light and Railroad Co., Elmira, N. Y.

Davis, L. H., Chief Engineer Tagona Water and Light Co.. Sault Ste. Marie, Ontario.

Huth, Frank, Secretary and Treasurer Water Works, Nazareth, Pa.

Newton, S. O., Manager City of Weatherford Water, Light and Ice Co., Weatherford, Texas.

Peck, John W., Superintendent Water Works, Evansville, Ind.

Reimer, Arthur A., Superintendent Water Department, City Hall, East Orange, N. J.

Sloane, D. M., Secretary and Treasurer Ohio Valley Water Co., 409 Lincoln Avenue, Belleview, Ohio.

Snell, James R., Superintendent Amsterdam Water Works, Amsterdam, N. Y.

Warner, B. M., General Superintendent Southern California Mountain Water Co., Union Building, San Diego, Cal.

Warren, Geo. C., President Board of Water Commissioners, Saginaw, Mich.

Wilcox, W. J., Superintendent San Jose Water Co., San Jose, Cal.

Wisler, James M., Superintendent Water Works, 1128 Woodville Street, Toledo, Ohio.

For Associate Membership.

Addressograph Co., Manufacturers Addressing Machines, 232 W. Van Buren, Chicago, Ill.

The Atlas Portland Cement Co., 30 Broad St., New York, N. Y.

Booth, L. M. Company, Water Softening and Purification, 136 Liberty Street, New York, N. Y.

Coffin Valve Company, Dorchester, Boston, Mass.

Cochrane Chemical Company, Manufacturers Alum, 55 Kilby Street, Boston, Mass.

Costello, Geo. M., President Cancos Manufacturing Co., Manufacturers Steam Packings, 146 North 2nd St., Phila., Pa.

East Jersey Pipe Company, The, 71 Broadway, New York, N. Y.

Excelsior Wooden Pipe Company, Manufacturers and Builders of Wooden Stave Pipe, 220 Broadway, New York, N. Y.

Gould, Norman, Secretary The Goulds Manufacturing Co., Seneca Falls, N. Y.

Hudson Contracting Co., Contractors for Cleaning Water Mains, 27 William Street, New York City.

Merrill, Wm. B. & Co., Metallic Packing, Boston, Mass.

Pitometer Company, The, 220 Broadway, New York, N. Y.

Seagrave, F. S., Hydraulic Cut-Off Valves, Detroit, Mich.

United Water Improvement Co., 1420 Pennsylvania Building, Philadelphia, Pa.

Van Winkle, W. H., President and General Manager Water Works Equipment Co., 180 Broadway, New York, N. Y.

PRESIDENT'S ADDRESS.

MEMBERS OF THE AMERICAN WATER WORKS ASSOCIATION, GENTLEMEN:—

During the twenty-five years of existence of this Association, much advancement has been made, many problems have been brought before you and many solved tending toward a betterment of water supplies; a most important question and probably the one of most vital interest to your people. As your Past President has said, probably the advance has not been as rapid as in other lines of engineering, still what has been done has been substantial.

There is still much to be done. Your Committee has just succeeded after hard and laborious work, requiring attendance at numerous meetings, and unstinted devotion to their duty, in having adopted a standard hose and nozzle thread. Why not go further with this and adopt a standard for cap nuts for fire hydrants?

It is sincerely hoped that engineers and representatives of Water Works and Municipalities will use their best efforts to place the results of the Committee's work before their people for adoption and actual practice, and it will be gratifying to the Association to learn of active steps already being taken.

We should not stop at receiving the report of the Committee, but should go farther and urge the adoption of their suggestions. It may prove costly to do so in many cases, but as the interests and protection of your people are involved, cost should be a secondary consideration.

A report of the Committee on Water Works Standards will be presented at this meeting and will contain many valuable suggestions for action by our members. This report has been delayed on account of the continued illness and ultimately the lamented death of its Chairman, Mr. Croes. The Committee has done excellent work and should be continued.

It is gratifying to note the constant increase in membership, and attendance at the meetings, and while it is impossible to allot to each member time to discuss his individual experiences, it is nevertheless important that he should attend the meetings to listen to and discuss the matters brought before it of importance to him.

Too much cannot be said of the work that has been done, nor can too much encouragement be given to those to whom you have entrusted the investigation of subjects brought before the convention. Your presence adds greatly.

The many valuable papers brought before you show not only the interest the writers are taking in the advancement of the Association, but also show their willingness to impart to you the result of their labors.

It was not my purpose or intent in taking up the subjects I did, to dwell upon them for any length of time, nor do I intend to speak of the many important subjects which are to be brought before you. I merely wish to emphasize the fact that co-operation is not only necessary to obtaining results, but also in carrying them out.

Our principal object is to improve conditions, not only commercial but educational, and undoubtedly much of this is accomplished by attending the meetings and being able to compare notes and meet with men who have given their energy and time to the improvement of water supplies.

In conclusion I desire to say, that as the honor conferred upon me at the 25th Annual Convention is about to be conferred upon another, I wish to thank the members for that honor, and for the able manner in which they have supported me, and sincerely hope that they will lend the same support to those that follow.

REPORTS OF COMMITTEES.

EXECUTIVE COMMITTEE.

To the American Water Works Association:

Gentlemen:—

Your Executive Committee beg leave to report that they have examined all of the applications filed for membership in this Association since the last Annual Meeting, amounting to 10 individual active, 13 corporate active, and 15 associate, and recommend the election of said applicants in their respective classes.

They examined the report of the Secretary and Treasurer, and have approved the same.

Your Committee has further fixed the salary of the Secretary and Treasurer at the same amount as the preceding year.

Your Committee has received a number of invitations for this Association to hold its next convention in various cities therein named, and herewith submits same to the Association for action in due course.

Your Committee further have to report, with deep regret, the decease of the following members during the past year:

John Anderson,
Charles Hood,
H. H. Laing,
J. B. Powers,
William Ryle,
J. J. R. Croes.

All of which is respectfully submitted.

B. C. Adkins,
Geo. H. Felix,
John B. Heim,
H. A. Dill,
H. E. Keeler,
D. H. Maury,
Alexander Milne,
John M. Diven,
Committee.

On motion, the foregoing report was received, and adopted.

SECRETARY-TREASURER.

Membership.

On roll at close of last convention:			
Honorary	7		
Active	411		
Associate	77		
Total	495		495
Losses during the year:			
By resignation, Active	10		
By resignation, Associate	5	15	
By death, Active		6	
Dropped, Active	9		
Dropped, Associate	2	11	32
			463
Reinstated			2
Number in good standing on Roll			465
Applications to be acted upon at this convention:			
Individual Active	103		
Corporate Active	12		
Associate	15		131
			596

Financial Statement.

Receipts:—

Cash on hand at close of last convention			$ 36.46
Received for initiation fees			600.00
Received for annual dues			2,520.00
Received for advertisements in proceedings			736.00
Received from sale of proceedings			11.25
Received from contributions to deficiency fund			344.00
Received from profit on binding proceedings			5.50
Total receipts			$4,253.21

Disbursements:—

Convention expenses		$ 266.10	
Stenographer, 1905 convention		135.45	
Office expenses		299.85	
Postage and express on proceedings		133.82	
Postage		133.90	
Association badges (one badge on hand)		4.00	
Printing proceedings of 1905 convention		1,135.85	
Interest and discounts (collection on checks)		11.73	
Members copies of papers		40.53	
Advertising (circulars to all water works)		94.30	
Advance copies of papers (for this convention)		292.24	
Expense insurance committee		9.98	
Dues in other associations (National Fire Protection Association for two years)		30.00	
Salary Secretary-Treasurer:			
Back salary	$ 301.66		
Current year	800.00		
		1,101.66	
Advanced Shepperd-Burnham Co., acct. printing 1906 proceedings	$ 180.73		
Balance cash on hand	383.07	563.80	
			$4,253.21

On motion of Mr. Holmes, duly seconded, report was received and adopted.

FINANCE COMMITTEE.

To the American Works Association:

Gentlemen:

Your Finance Committee would respectfully report that they have carefully examined all the books, papers and vouchers of the Secretary and Treasurer, including his report, and we find the same to be correct in every particular.

We have also examined the report of the bank wherein the funds of the Association are deposited, and find that the amount of money shown by the Treasurer's report to be on hand is actually on deposit in the bank.

We are also pleased to report that the books of account are now in strictly first class and proper form and condition, and that the finances appear to be in much better condition than for a long time in the past.

Respectfully submitted,
H. E. Keeler, Chairman,
Howard A. Dill,
A. A. Tucker,
Committee.

The report of the Committee was adopted and ordered spread on the minutes.

PUBLICATION COMMITTEE.

To the American Water Works Association:

Gentlemen:

Your Publication Committee respectfully reports that it has through correspondence considered all of the papers which were sent to it in advance of the meeting, and has also held a meeting of its members prior to the opening of this convention.

The results of the recommendations embodied in the report of the Publication Committee of last year have been exceedingly gratifying. With very few exceptions papers have been presented for review by the Committee long enough before the convention to enable advance copies of them to be printed and distributed to the members. The papers themselves are of an unusually high order, and the Committee has been called upon to do little or nothing in the way of correction.

Your Committee, therefore, feels that any recommendations that it should make this year should be only in the line of emphasizing the recommendations of the previous Committee, and especially wherein that Committee said:

"Your Publication Committee would suggest that its work cannot be thorough and efficient unless all papers be in the hands of the Committee at least thirty days in advance of any given convention; and if possible such papers should be submitted in duplicate. A uniform observance of this rule is vitally necessary to the proper review of the subject matter presented to this Society, and any failure to accord to the Committee this opportunity will work injustice not only to the Publication Committee and to the Society at large, but to the authors of papers as well."

All of which is respectfully submitted,

H. E. Keeler, Chairman,
Dabney H. Maury,
John M. Diven,
John W. Alvord,
Daniel W. Mead,
Committee.

The report was received and ordered spread on the minutes.

COMMITTEE ON ELECTROLYSIS.

June 21, 1906.

To the American Water Works Association:

So far as relief from electrolytic damage to water pipes is concerned, your Committee on Electrolysis is unable to report any encouraging change in the aspect of affairs since its report of a year ago.

The suits then pending or at issue remain practically in *statu quo,* and the injury to the pipes still goes on.

Your committee can find nothing in the developments of the past year to cause it to wish to alter the statements or the recommendations contained in its previous reports.

Respectfully submitted,

Dabney H. Maury,
J. Waldo Smith,
G. H. Benzenberg,
Committee on Electrolysis.

On motion of Mr. Sherrerd the report was received and spread upon the minutes.

COMMITTEE ON WATER WORKS STANDARDS.

To the American Water Works Association:

Gentlemen:

All our time was devoted to trying to get together a Conference Committee consisting of three members each from the New England Water Works Association, American Water Works Association, American Society for Testing Materials, Western Society of Engineers, and Manufacturers' Committee—making fifteen members of a general Conference Committee.

It was found impossible to get such a large committee together, and so the business was commenced by correspondence and by the meeting of the chairmen of these different committees.

After three meetings and a good deal of discussion, it was found impossible to come to any conclusion in this conference committee which could be presented to the regular committee on Water Works Standards of the Association; consequently we request that the committee be continued for further consideration of the subject.

Respectfully submitted,

Charles A. Hague, Chairman.

(Mr. Hague acted as chairman of the Committee by the special request of Mr. J. J. R. Croes, the original chairman of the Committee, and who is now deceased.)

On motion, duly seconded, the request was granted, and the Committee continued.

FIRE PROTECTION COMMITTEE.

To the American Water Works Association:

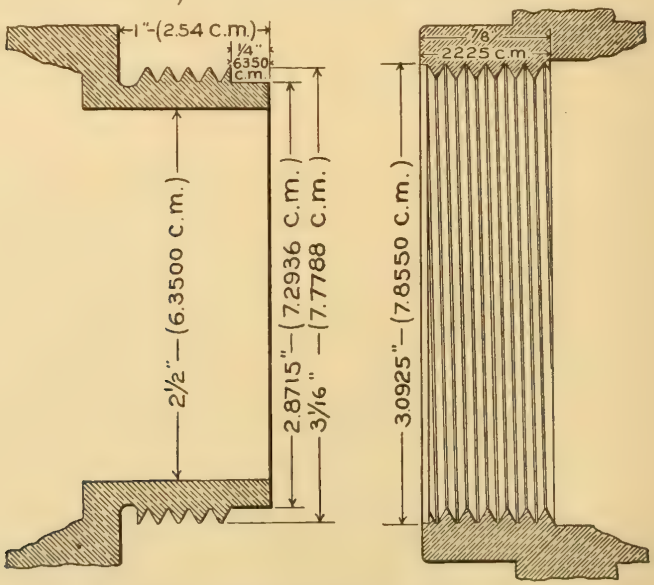
The Fire Protection Committee begs to report that since the meeting of the Association at West Baden, Ind., May 8th and 12th, 1905, considerable progress has been made by co-operation with the National Fire Protection Association in interesting other National Associations to accept and adopt the specifications which had been agreed upon by conference between our respective associations and first adopted by the American Water Works Association at West Baden, Ind., of a standard thread for fire hose couplings and hydrant nozzles of 7½

threads to the inch on a male coupling or hydrant nozzle of 2½ inches internal diameter and an outside diameter of 3 1-16 inches, and as the tables of other diameters and measurements have been published in former reports, we deem it not necessary to include same in this report, but attach hereto cuts

National Fire Protection Association Standard Hose Coupling.

	INCHES.	CENTIMETRES.
INSIDE DIAMETER OF HOSE COUPLING	2½	6.3500
NUMBER OF THREADS PER INCH 7½	.....	.....
BLANK END ON MALE PART	¼	.6350
OUTSIDE DIAMETER OF THREAD FINISHED	3/16	7.7788
DIAMETER AT ROOT OF THREAD	2.8715	7.2936
CLEARANCE BETWEEN MALE AND FEMALE THREADS	.03	.0762
TOTAL LENGTH OF THREADED MALE END	1.00	2.5400

60° V THREAD PATTERN $\frac{1}{100}$ INCH (0.0254 CENTIMETRE) CUT OFF TOP OF THREAD AND $\frac{1}{100}$ INCH (0.0254 CENTIMETRE) LEFT IN BOTTOM OF VALLEY. FEMALE END TO BE CUT $\frac{1}{8}$ INCH (0.3175 CENTIMETRE) SHORTER FOR ENDWISE CLEARANCE.



2½" SIZE (6.3500 C.m.)

showing all mechanical and technical details essential for clear understanding and guidance for manufacturing. This subject was brought to our attention through Mr. F. M. Griswold, chairman of similar committee of the National Fire Protection Association, and his committee has harmoniously and cheer-

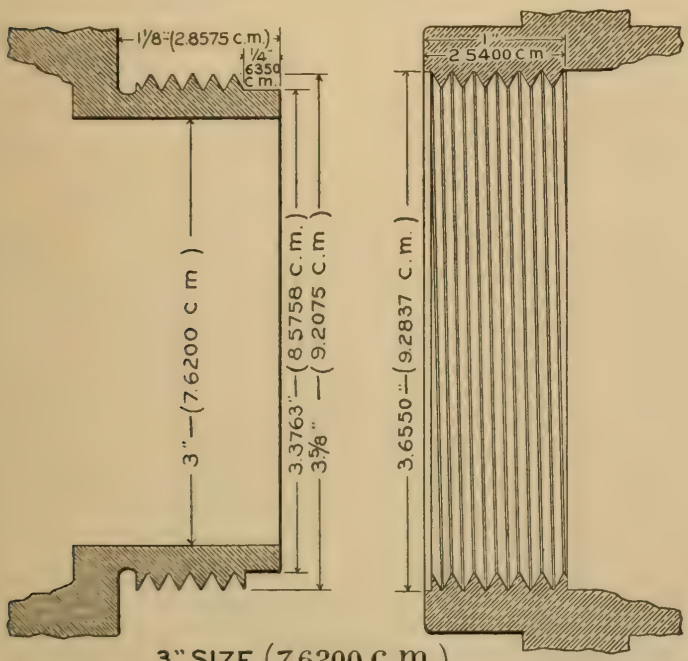
fully worked in co-operation with us to secure this standard.

As an indication of accomplishment we give below the names of associations and convention dates at which approvals of this standard was secured by practically unanimous consent of these organizations:

National Fire Protection Association Standard Hose Coupling.

	INCHES.	CENTIMETRES.
INSIDE DIAMETER OF HOSE COUPLING	3	7.6200
NUMBER OF THREADS PER INCH 6	.....	.....
BLANK END ON MALE PART	¼	.6350
OUTSIDE DIAMETER OF THREAD FINISHED	3⅝	9.2075
DIAMETER AT ROOT OF THREAD	3.3763	8.5758
CLEARANCE BETWEEN MALE AND FEMALE THREADS	03	.0762
TOTAL LENGTH OF THREADED MALE END	1⅛	2.8575

60° V THREAD PATTERN $\frac{1}{100}$ INCH (0 0254 CENTIMETRE).
CUT OFF TOP OF THREAD AND $\frac{1}{100}$ INCH (0.0254 CENTIMETRE) LEFT IN BOTTOM OF VALLEY. FEMALE END TO BE CUT ⅛ INCH (0 3175 CENTIMETRE) SHORTER FOR ENDWISE CLEARANCE



3" SIZE (7.6200 c.m.)

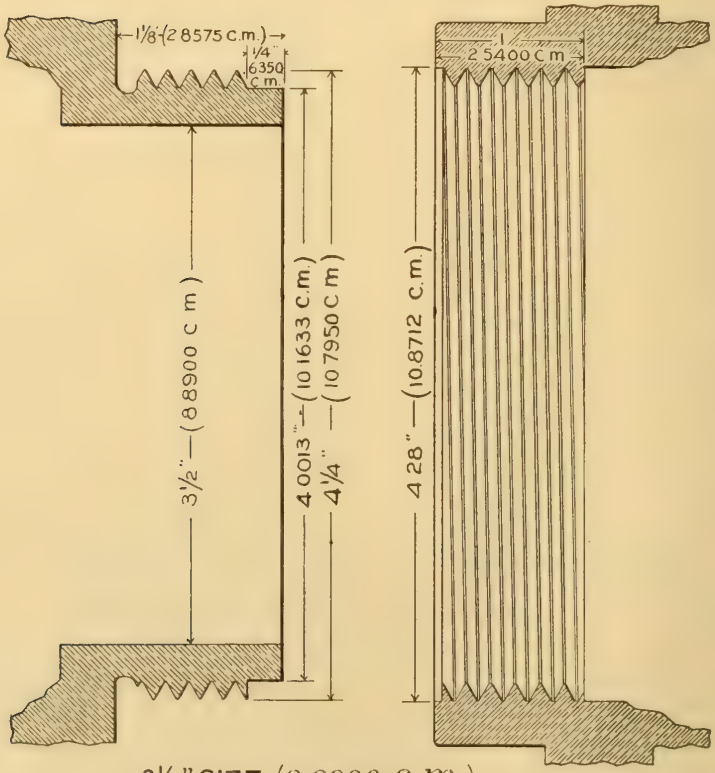
National Board of Fire Underwriters, New York, May 23, 1905.

National Fire Protection Association, New York, May 23, 1905.

National Fire Protection Association Standard Hose Coupling.

	INCHES.	CENTIMETRES.
INSIDE DIAMETER OF HOSE COUPLING	3½	8.8900
NUMBER OF THREADS PER INCH	6	
BLANK END ON MALE PART	¼	.6350
OUTSIDE DIAMETER OF THREAD FINISHED	4¼	10.7950
DIAMETER AT ROOT OF THREAD	4.0013	10.1633
CLEARANCE BETWEEN MALE AND FEMALE THREADS	.03	.0762
TOTAL LENGTH OF THREADED MALE END	1⅛	2.8575

60° V THREAD PATTERN $\frac{1}{100}$ INCH (0.0254 CENTIMETRE)
CUT OFF TOP OF THREAD AND $\frac{1}{100}$ INCH (0.0254 CENTIMETRE)
LEFT IN BOTTOM OF VALLEY. FEMALE END TO BE CUT $\frac{1}{8}$ INCH
(0.3175 CENTIMETRE) SHORTER FOR ENDWISE CLEARANCE.

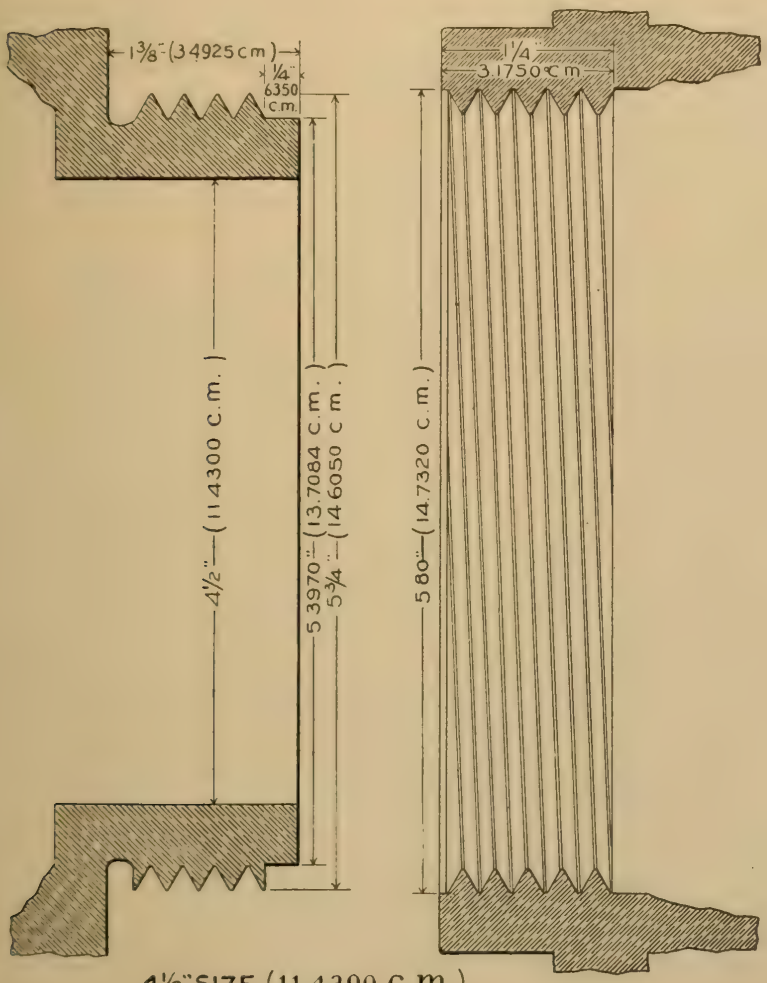


3½" SIZE (8.8900 C.M.)

National Fire Protection Association Standard Hose Coupling.

	INCHES	CENTIMETRES
INSIDE DIAMETER OF HOSE COUPLING	½	11.4300
NUMBER OF THREADS PER INCH	4	
BLANK END ON MALE PART	¼	.6350
OUTSIDE DIAMETER OF THREAD FINISHED	5¾	14.6050
DIAMETER AT ROOT OF THREAD	5.3970	13.7084
CLEARANCE BETWEEN MALE AND FEMALE THREADS	05	.1270
TOTAL LENGTH OF THREADED MALE END	1⅜	3.4925

60° V THREAD PATTERN $\frac{2}{100}$ INCH (0.0508 CENTIMETRE)
CUT OFF TOP OF THREAD AND $\frac{2}{100}$ INCH (0.0508 CENTIMETRE)
LEFT IN BOTTOM OF VALLEY. FEMALE END TO BE CUT ⅛ INCH
(0.3175 CENTIMETRE) SHORTER FOR ENDWISE CLEARANCE



4½" SIZE (11.4300 C.M.)

International Association of Fire Engineers, Duluth, Minn., August 19, 1905.

North Carolina State Firemen's Association, Winston, N. C., August 1905.

National Firemen's Association, Kansas City, August 30, 1905.

New England Water Works Association, New York, Sept. 14, 1905.

Pennsylvania Water Works Association, Atlantic City, N. J., September, 1905.

In connection with this information we deem it important to report that St. Louis, Mo., has appropriated $50,000 to begin the necessary changes to conform to this standard, and Nashville, Tenn., has ordered new hydrants with steamer connections also in conformity with this standard. Several new water works plants which are now being built in the smaller towns and cities have been advised by the insurance and consulting engineers to adopt this standard and materials have been ordered and are being installed in conformity with this advice. President Sherrerd in his address at West Baden referred to the subject of sizes of fire mains which has special reference to the hydrant branch connection, and we, therefore, recommend that the minimum size of hydrant connection shall not be less than 6 inches.

At the West Baden convention our committee reported that it was of equal importance to adopt a standard nut to be used upon the operating stem of hydrants and our report was accepted by the association, and upon investigation and correspondence with hydrant manufacturers during the past year it has developed that 90 per cent. of the manufacturers favor the size and shape that this committee will recommend and which was adopted by the National Fire Protection Association in May, 1906, at Chicago. We recommend for adoption a nut of pentagon shape an inch and a half from flat to point, cap nut also to be pentagon of same size.

This committee also recommends that the hydrant shall open by turning the stem to the left, but would caution against adopting this direction of opening unless the entire system of the city hydrants is changed to agree therewith.

We further recommend that the top circumference of the hydrant, in a suitable place surrounding the operating nut, bear a raised arrow device pointing in this direction to open, the arrow to be at least 2½ inches long, and letters of at least ¾-inch in height be used. The committee further reports that the chairman elected as a delegate at West Baden has attended three conventions during the year, without cost to the Association on their fire protection matters, namely: The National Fire Protection Association, New York, May 23, 1905; The International Association of Fire Engineers, Duluth, Minn., August 19, 1905; The National Fire Protection Association, May 22 and 24, 1906, at Chicago.

Respectfully submitted,

C. H. Campbell, Chairman,
F. W. Shepperd,
M. R. Sherrerd,
R. J. Thomas,
Geo. H. Felix,
Chas. A. Hague.

Mr. Campbell: We have made a supplementary report on other subjects which have been before us and which we thought best to report upon separately. After the convention has acted upon the main report Mr. Sherrerd will please read the supplementary report.

On motion of Mr. Heim the main report was adopted and ordered printed in the proceedings.

SUPPLEMENTARY REPORT OF THE FIRE PROTECTION COMMITTEE.

Whereas in response to the invitation of this committee extended to all meter manufacturers and others interested in the subject of measuring and protecting private fire service supplies, we have, in addition to the device presented by Mr. Jas. A. Tilden and referred to in our report to the West Baden Convention, been informed of certain improvements made in a similar device designed by the inspection department of the "Factory Mutuals" and presented to the committee by Mr. E. V. French.

Therefore your committee recommend that Mr. French be

requested to describe to the convention the device proposed by him and his associates.

Respectfully submitted,

C. H. Campbell, Chairman,
F. W. Shepperd,
M. R. Sherrerd,
R. J. Thomas,
Chas. A. Hague,
Geo. H. Felix.

REMARKS OF MR. E. V. FRENCH, OF THE ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES.

Mr. President and gentlemen, there is not very much to say perhaps that is new, but it seemed only right that a little should be said, if you desire it, as to just what progress has been made on the fire service meter work. You remember that several years ago at Detroit we took up this question of fire services. There were several engineers from the Underwriters there, and we outlined as well as we could the things that we were striving for and the difficulties that we were meeting, and we promised to do our best to find a solution of these difficulties.

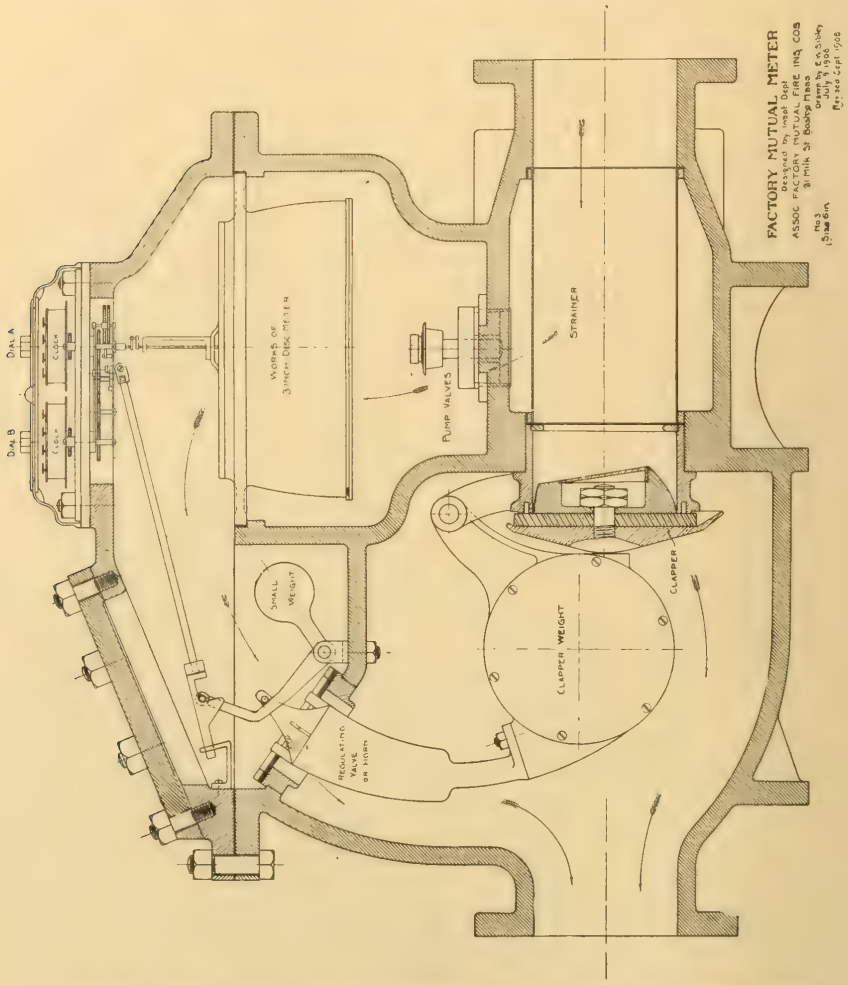
At West Baden last year a good deal of the result of the work which has been done since the Detroit convention was presented to you by some of our friends—I was not fortunate enough to be there myself—and we would now like to again make it clear that the engineers connected with the fire protection work have given very careful study to this problem, realizing that the water works men were having considerable difficulties to meet and that a solution would only be reached by full co-operation between us.

The Factory Mutual Companies, having a large number of protected manufacturing properties, were perhaps the first to meet this difficulty in its intensity and we very strongly urged on several public occasions, and also at many other times in ordinary conversation, that the meter people get something that would do the needed work; but for a considerable time nothing was offered. We soon found that the demand for some kind of a meter or detecting device was very strong, and the

tendency to cut off the service or to make other restrictions which very seriously interfered with the fire protection was such that we felt compelled to try ourselves to devise something that would meet the requirements. The majority of the ordinary commercial meters with rotating pistons or disks we considered objectionable for fire supplies, because under some conditions the moving parts may become blocked so as to interfere with the service. Furthermore, many of them cause a very large friction loss. Of course, for fire fighting, a large quantity of water at good pressure is necessary; consequently there must be a free inlet from the public mains into the mill yard, or protected building. Again, even with free meters which cannot produce serious friction loss it is quite customary to put in some sort of a strainer or fish-trap; and in our tests we found that while these will work satisfactorily with ordinary drafts, when one begins to draw the large quantity of water which a fire requires the increased flow will sweep along collections of pipe scale, bits of hemp, leaves, etc., such as gather in the bottom of mains, and will deposit these on the strainer, sometimes considerably choking it; so that even if the meter itself is unobjectionable, the fish-trap or strainer used with it is likely to become a source of danger. In a test which we made of a large meter some time ago, a twenty minutes' run was sufficient to cover about half of the surface of a fairly liberal fish-trap, indicating that in the event of a fire lasting several hours the obstructions would probably become serious.

These were the causes which led us into meter designing, a work outside of our field, and which we did not desire to go into and only took up to prevent the restrictions of fire services which seemed inevitable unless something was produced to meet the difficulty. Like all who attempt similar work, we found the problem more difficult than we had anticipated. It has taken longer and cost more than we thought it would; but having started we could not turn back. The goal that we set for ourselves was some kind of a metering device that would fulfill the needs of the water department in measuring very small flows and leaks, i. e., small drafts of water for any purpose, proper or improper; and which at the same time could measure large flows with sufficient accuracy for practicable purposes. While accomplishing this the design must be

such that the meter could not under any condition become obstructed or in any way interfered with so as to impair the fire service. I think we have accomplished at least a large part of what we started to do. There is undoubtedly much to be



learned from actual experience with the device, but along these general lines one solution of the problem will surely come. The work already done is the result of the thought and work of several of the men in our engineering department, each of whom has contributed something as the problem developed.

Many of you are familiar with the device in a general way, so that I will but briefly describe it with its latest developments. By referring to the cut it will be seen that the meter consists of a metered by-pass and a straight passage unobstructed except by a clapper. The water entering the by-pass goes through a cylindrical strainer, arranged to be washed by the flow through the main passage, thence by the small check valves and the disk meter and out the horn orifice. The disk meter records the flow through it on a dial in the ordinary manner. A second dial geared from the first is arranged to be thrown into mesh whenever the clapper opens and thus record the flow in the main passage. The sum of the dial readings gives the total flow.

Attached to the clapper is a horn (whose shape has been determined by experiment) which regulates the size of the by-pass opening so that an exact ratio of flow is maintained in the passages. Attached to the clapper will be noted a disk and a block; these parts are for the purpose of giving a uniform and rapid clapper opening.

The clapper seat is made with a groove which is open to the atmosphere, thus making a differential seat, the effect of which is to keep the clapper shut until the flow through the by-pass causes a loss sufficient to overcome this action (in present design this is 6 per cent. of static pressure). When the clapper leaves its seat it does so with a jump, because destroying the differential is equivalent to removing weight suddenly. This jump is utilized in throwing into gear the second dial previously mentioned. The clapper also closes early due to the weight and shape of the parts.

The meter therefore acts as follows: For small flows all the water goes through the by-pass and is recorded by the disk meter. At about 150 G.P.M. (with static of 70 pounds) the clapper jumps open and causes the second dial to be thrown into gear. After the clapper opens all further flow of water is measured proportionately. From the time the clapper opens until it reaches its stop (from about 150 to 1100 G.P.M.) the ratio of flow in the passages is regulated by the horn. When the clapper reaches its stop the proportionate readings are still maintained, because the area of the passages and consequently the ratios of losses remain constant.

This in brief is the meter as it stands to-day. Now as to the present position of the Underwriters in regard to fire services —and I think what I say will apply to Underwriters in general as well as to the Factory Mutuals—the feeling is this, that in a private fire system there should not be any considerable draft off of the fire pipes for manufacturing purposes and preferably the fire pipes should be reserved for fire purposes only with no connection from them for any other purpose.

We have for some time been asking the mills to put in a separate system of pipes for the water that they want for other than fire purposes, and such services can be metered in any way the water department desires. With this arrangement the chance of misuse of the fire system is much reduced. If through misunderstanding, or a desire to take what does not belong to them, some one in the mill does draw water from the fire pipes and you feel you must have some guard over this, then we are to-day advising the use of some of the detector devices such as were described last year. In a majority of cases the detector will give all the guard that is necessary over the fire service. When, however, cases arise where hydrants are opened and water taken now and then in larger quantities, as for condensers, boiler washing, mortar making, etc., so that a measurement of all flows becomes necessary, then the device just described can be used. It will measure the small flows the same as the detector, and the large flows as explained, with all the accuracy I think that anybody would ever ask for.

So then we have these three methods: First, the separation of the systems; second, if separation is not enough and you feel that some guard is necessary, the placing of a detector device; third, if you want to go still further and measure not only the smaller flows but the larger ones this device that we have been working on is about to be available.

I would like to make it clear that the Underwriters are not going to stick closely to any one device. The detector which you heard about last year, and this device, are the only ones which we can speak of definitely to-day; but just as soon as there are on the market other devices equally satisfactory and equally safe we shall put them on the accepted list,

just as we have done in the case of automatic sprinklers and other things to which we give approval without qualification. We stand in the position that we are ready to accept anything that safely does the work; and we offer something to take care of immediate needs.

Now in order that everybody may have a chance to become familiar with the meter, we have brought down one of them which was being tested in Mr. Thomas's testing station at the Lowell pumping plant. We asked Mr. Tilden, who manufactured it, to bring it here and put it among his productions, so that any one who wanted to see the general style of the device could do so. It is at the foot of the stairs.

I think this covers the whole case. I think I may say for the Underwriters at large that whenever difficulties arise in regard to fire service meters we shall all be glad to carefully consider them and seek a solution. Those of us who have been earnestly studying this problem for years all feel that our interests are identical and that it is mutually desirable to work out some satisfactory arrangement which will permit giving property the kind of protection that it needs without introducing other troublesome features. I think you will all agree that full protection is a very great benefit to the community as a whole. At the same time we appreciate that it must be possible to give this without running the chances of losing water through irresponsible or dishonest persons; and in any case where there is special difficulty or trouble we are always ready to consider it and do all that we can to straighten matters out. I thank you.

Mr. F. L. Fuller: May I ask one question? I understood you to say that the check valve closed the other opening. Am I right?

Mr. French: Yes, substantially. When the check jumps from its seat the horn jumps into the horn ring and nearly closes it. Then as the clapper opens further, the horn, being smaller as it goes in, opens the port wider, consequently increasing the flow of water through the small meter as the water through the main channel increases, thus keeping the proportion the same.

Mr. F. L. Fuller: In using hydrants or anything of that kind is there a flow of water through both openings?

MR. FRENCH: Yes, sir.

MR. F. L. FULLER: Do you have trouble with large supplies, and do you have to increase the size of the meter in proportion to the size of the service?

MR. FRENCH: Our idea is that larger meters would be built, but this has not yet been done. Our feeling is that even in a large system having perhaps an eight inch or ten inch service from the city, it would not be desirable to use more water than from a small system. The underwriters' objection to the use of a large quantity of water from the fire system comes from the fact that if while manufacturing connections are being used a fire occurs and the fire pump is started and brings the pressure from the normal public pressure of, say 60 pounds, up to a fire pressure of 100 pounds, then if the manufacturing connections are open the fire pump discharges into these manufacturing connections and does not give its full capacity to the fire apparatus. The only exceptions are in some very large plants where a double system of pipes would not be feasible. There the only thing to do is to put on safe meters and have fire pumps enough so as not only to supply the manufacturing draft but the fire draft in addition. In the average case it is certainly better to have no draft, or at least a very small one, from the fire pipes.

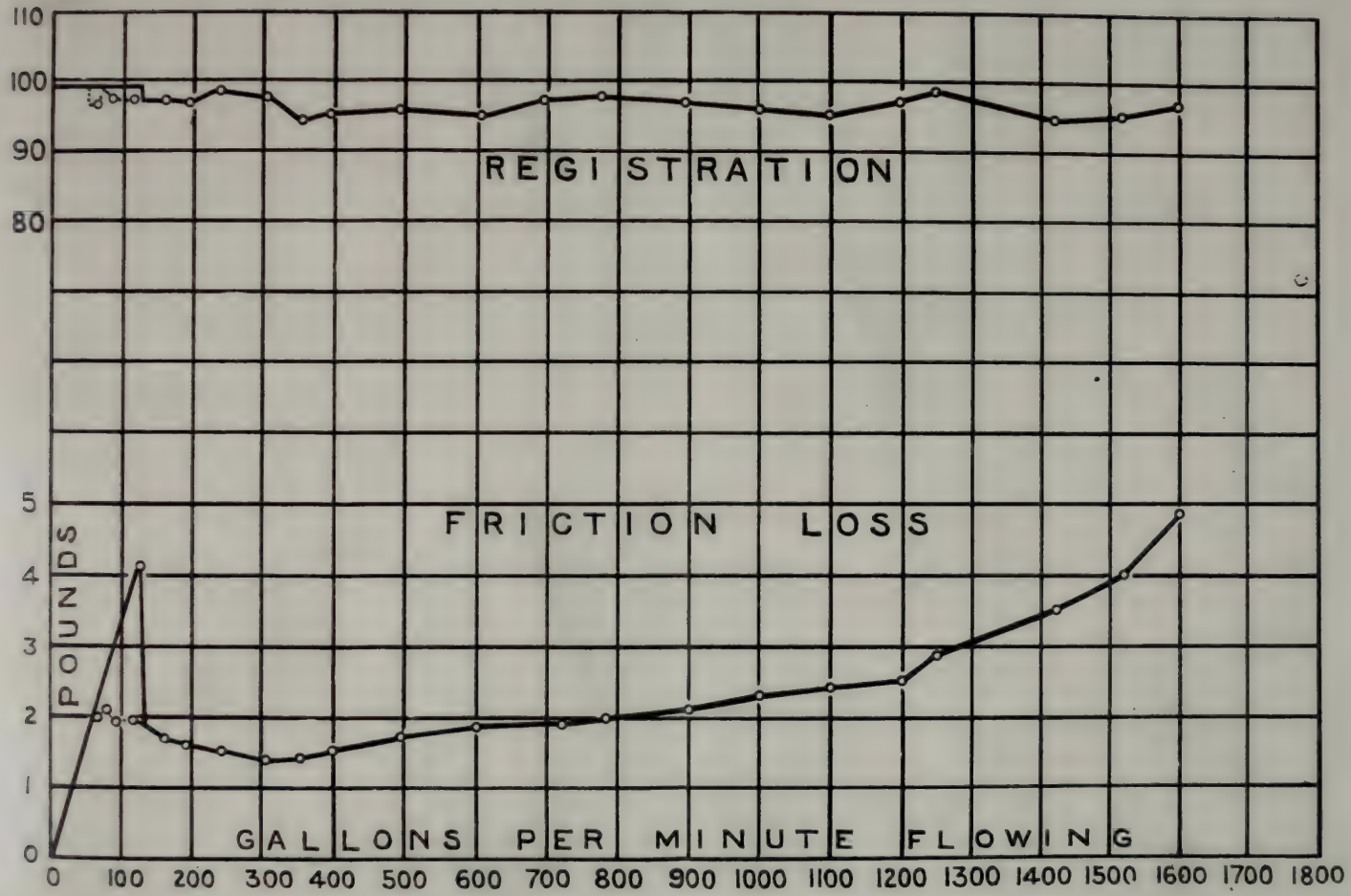
Another objection to constant draft on the fire pipes is that it hastens corrosion, thus lessening the capacity of the pipes. The more, therefore, we can keep the things entirely separate the less chance there is of trouble.

MR. F. L. FULLER: If the hydrants in the mill yard do not supply all the water that is needed, would the service come from the city supply?

MR. FRENCH: Yes, ordinarily. As a usual thing when a fire occurs the first thing that opens is the automatic sprinklers. They take some water, which is usually public water. If the fire is of any magnitude, the theory is, and the rule is, that the fire pump will be started instantly and will bring the pressure up to about 100 pounds. Then if the fire is bad and more water is needed and the pump cannot hold the pressure up, the public water comes in. In cases where the public water pressure is 100 pounds or more you might use that

rather than the pump; but those cases are the exception.

fire protection than one six-inch branch would supply; therefore, it might be safe to give several six-inch branches for


110
100
90
80
REGISTRATION
5
4
3
2
1
0
POUNDS
FRICTION LOSS
GALLONS PER MINUTE FLOWING
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800

rather than the pump; but those cases are the exception.

MR. ROSAMOND: If your main channel is increased from six inches to eight inches, would that increase a three-inch meter to a four-inch, five-inch, or six-inch?

MR. FRENCH: Not necessarily. It would be possible to build this device and put any size meter in the by-pass. With the six-inch size the three-inch meter fits it best. I think there would be no difficulty in building an eight-inch device with a three-inch meter; it would simply mean that instead of multiplying the water that went through the small meter by about 10, as in this case, to get the total flow you might have to multiply by 20.

MR. BOLLING: Are the smaller meters more sensitive than larger ones?

MR. FRENCH: Yes, in general. The friction loss through this device is so comparatively small that in some cases with an eight-inch service you can use an eight-inch by six-inch reducer, with a six by eight-inch enlarger. Even then the friction loss through it, with all the water that an eight-inch pipe can bring, is not excessive.

MR. SHERRERD: I am rather glad to see this meter is at present only adapted for a six-inch size, because the question that has been asked in regard to larger size leads up to another phase of this subject which it seems to me we as water works men ought to consider seriously; that is, as to whether larger fire services than six-inch, for instance, should be allowed to be taken off from street mains? I believe that some limit in size should be adopted in each city, perhaps proportioned to the size of the mains drawn from. My suggestion would be to allow no larger private fire service supplies than six-inch, for the reason that the superintendent must not only protect the individual risk, but he must protect the surrounding property that depends on the city's fire protection. If larger services than six-inch are taken off the ordinary streams and the fire in a protected risk gets beyond control, should the walls fall and that pipe become broken, you have a very serious crippling of the city's fire protection as a result. There are a good many large buildings that would require more water for fire protection than one six-inch branch would supply; therefore, it might be safe to give several six-inch branches for

private fire protection perhaps coming off the same street main, provided some other condition would be guarded against. That is, those branches should be taken into different parts of the mill, and where the cellar, for instance, is divided by partition walls, so that the falling of the main wall in the event of fire would not endanger the entire supply, or more than one of those services.

Mr. French: As Mr. Sherrerd says, I think it is very necessary that the fire protection should be put in so that the destruction of no one building would cripple every other part of the system. It has been our practice for years to put in a controlling gate with an indicator on it on every service into a mill yard and a similar gate on every connection into a building for sprinklers or stand-pipes. We do this because if any break occurs we must be able to quickly cut off the water. We endeavor to have these gates so marked that their purpose will be understood by any one, and then to always have them placed so that they will be accessible, no matter how serious a fire is burning. In a very few cases a four-inch service has been the limit, but with even a comparatively small property you can not get the water that may be needed through a four-inch pipe unless it is very short. There would not from the capacity side be any objection to supplying two six-inch connections rather than one eight-inch, but this adds more complications and makes more fittings. I think we should consider the safeguards on such private mains as mentioned above as a more important factor than the size of the services.

Mr. Hague: I had an experience in that very line that Mr. French brings up. A fire occurred in a cotton oil mill. The sprinkler pipes had a shut-off in the yard, but the fire came so suddenly and got under such headway that part of the building fell and broke the sprinkler pipe. At that time the fire was so hot that no one could go in the yard and shut the sprinkler pipe off. There was no shut-off in the street. The fire service was direct. The recording gauge showed 120 pounds at the water station. By the time they got a couple of steamers there the property was destroyed. If they had had a shut-off in the street they could have gotten water on the fire thirty minutes sooner. That matter of having a shut-off

in the street where the fire cannot drive you away from it is a very vital point.

MR. BOLLING: I think that at the Chicago Convention Mr. W. A. Alexander, of Wilkinsburg, Pa., had an automatic device for cutting off water in the event of walls falling and destroying your opportunity for getting to a valve located either in the yard or in the street. My recollection is that he was to report further to this Convention. Has such report been made? It was an automatic device for letting a gate drop in the fire connection service so as to cut the water off completely in the event of a falling wall.

SECRETARY: This will be found under the discussion on "Private Fire Services" on page 54 of the Proceedings of the Twenty-second Annual Convention (Chicago), and a drawing of the device accompanying the report of the committee on "Regulation and Control of Private Fire Services" at page 245 of the same.

COMMITTEE ON RESOLUTIONS.

TO THE AMERICAN WATER WORKS ASSOCIATION:
GENTLEMEN:

Your Committee have the honor to report and to recommend for adoption, the following:

WHEREAS, We have enjoyed at this Twenty-sixth Annual Convention of the American Water Works Association delightful weather, and beautiful surroundings, in a city rich with associations of the historic past of our country's glorious career, whose officials and citizens as well as our own resident members have received us with cordial welcome and done all things to contribute to our comfort and to render our deliberations agreeable as well as profitable, therefore be it

RESOLVED, That a formal expression of our gratitude and appreciation is fitting and desirable, and that this Association hereby tenders a vote of thanks and highest appreciation to the following, viz:

To His Excellency, the Lieutenant-Governor of Massachusetts, Eben S. Draper; and to His Honor, Mayor John F. Fitzgerald, who respectively in behalf of the State and City gave us welcome, and evidenced by their remarks their public

spirit and their intelligent understanding of water works matters, and the importance of a proper administration of the same to all communities;

To the President of the Massachusetts Institute of Technology and to its faculty generally, who furnished us not only the use of Huntington Hall for our deliberations, and gave us every facility for the transaction of the affairs of the Convention, but also provided our administrative officers with suitable and commodious headquarters, and placed their subordinates at our disposal. In this connection we feel it is proper that especial mention shoul be made of the special exhibit of Sanitary Science under the charge of Professor Sedgwick, the purpose of which we, as waterworks men, judge to be most worthy and commendable in the interest of the public health;

To the New England Water Works Association, who in the person of their President, Professor Sedgwick, gave us welcome, and would have been glad to be our hosts, had not that office been the province of our local members, to whose Local Committee, Mr. J. A. Tilden, Chairman, we are under lasting obligations for manifold courtesies and attentions;

To the Boston Society of Civil Engineers, who welcomed us through their President, Mr. Frank W. Hodgdon;

To the authors of the various papers by which we were interested and instructed, and which were of an unusually high order of excellence and technical value;

To the Postal Telegraph Co., the N. E. Telephone Co., the Globe Wernicke Co. for special favors, and to the daily and technical press.

H. E. Keeler,
C. H. Campbell,
Dabney H. Maury,
Committee.

On motion, report adopted unanimously.

REPORT OF SPECIAL COMMITTEE ON DEATH OF PAST PRESIDENT RYLE.

Having learned with the most profound regret of the death of our fellow member and former President, William Ryle, we beg to present the following memorial in response to the re-

quest of the Association through the resolution offered and adopted, to-day:

We all knew, loved, and respected William Ryle as a man, a citizen and an able, competent and earnest member of the American Water Works Association for nearly a quarter of a century.

His cheerful face, his genial manner and his friendly ways were known to all of us; and although the inevitable march of time will bring to all a common fate, it is nevertheless with the deepest feelings that we note that another friend and fellow member has passed away.

William Ryle was well and widely known in the city of his home, Paterson, N. J., and throughout the country wherever a member of our Association could be found, and to many hundreds as well, outside of our ranks.

JOHN C. KELLEY,
CHAS. A. HAGUE,
JOHN CAULFIELD.

MR. KELLEY: I move that the resolution be spread in full upon the minutes and a copy sent to the family of the deceased.

Motion unanimously agreed to by a rising vote.

COMMUNICATIONS.

A cablegram was received from Mr. N. P. Simin, extending the greetings of the Russian Water Works Association to the American Water Works Association.

The Secretary was directed to make suitable acknowledgement of the communication.

The following letter was received by Mr. SHERRERD from Mr. Simin, and on motion the profer was accepted.

N. P. SIMIN, C. E., PRESIDENT OF THE PERMANENT BUREAU OF THE RUSSIAN WATER WORKS ASSOCIATION, RUSSIA, MOSCOW, RAZGULAY, 3.

THE 12-25 JUNE, 1906.

MR. M. R. SHERRERD, PRESIDENT OF THE AMERICAN WATER WORKS ASSOCIATION, NEWARK, N. J.

DEAR SIR:

From 1893 had we seven meetings of the Russian Water Works Association; their works are printed in seven volumes;

besides our congresses have worked out a standard of cast iron piping and connection details which are exposed in tables and drawings.

I address myself to you with a proposal to organize a return change of printed works and reports of the American and Russian Associations.

At the same time I address myself also with such a proposal to the Bureaus of the German, English and French Associations and I hope that my proposal of a relation of national Associations will be welcomed.

If you are consenting to it, please give me an answer; I will send you then all the printed matter of the Russian Association to the Bureau of the American Association which address please communicate to me.

Yours very truly,
President of the Permanent Bureau,
N. P. SIMIN.

Secretary,
T. HALTURINE.

TUESDAY, July 10TH, 1906.

AFTERNOON SESSION.

After presentation of the President's address and the reports of the various committees the following papers were read:

1. Filtration of Water, the Element We Have to Deal With, Mr. F. A. W. Davis.
2. Notes on Sewage Disposal and Public Water Supplies, by Mr. M. N. Baker.
3. The Greatest Typhoid Epidemics, by Dr. Geo. A. Soper.
4. River Pollution, by Mr. M. O. Leighton.

The last three were discussed together, the discussion being quite general. A number of written discussions were also received on these papers.

EVENING SESSION.

The following papers were presented at the evening session:

1. Extension and Improvement of the Supply Main, Yarmouth, N. S., by Mr. George H. Robertson. In the absence of the writer this paper was presented by the Secretary, and being largely descriptive called forth no discussion.

2. Water Softening for Municipal Plants, by Mr. Geo. W. Fuller. This paper was illustrated with numerous lantern slides and was discussed by Messrs. P. A. Maignen, C. A. Brown, Monfort, Reimer, and by Prof. Bartow and others.

3. A Pictorial Appeal—Water Works Too, by Mr. H. F. Dunham. This paper was, also, illustrated with many lantern slides, but being mostly descriptive called out no discussion.

WEDNESDAY, JULY 11TH, 1906.

MORNING SESSION.

This session was entirely devoted to the election of officers for the ensuing year and the selection of the place for holding the 1907 convention.

The election of officers resulted as follows:

President, Mr. Dabney H. Maury, Peoria, Ill.

1st Vice President, Mr. Geo. H. Felix, Reading, Pa.

2nd Vice President, Mr. John B. Heim, Madison, Wis.

3rd. Vice President, Mr. Alexander Milne, St. Catharines, Ontario.

4th Vice President, Mr. D. W. French, Hoboken, N. J.

5th Vice President, Dr. W. P. Mason, Troy, N. Y.

Finance Committee: H. E. Keeler, Chicago, Ill.; Howard A. Dill, Richmond, Ind.; A. A. Tucker, Memphis, Tenn.

Secretary-Treasurer: J. M. Diven, Charleston, S. C.

Toronto, Ont., was selected as the place for holding the 1907 convention.

Mr. C. H. Campbell was elected Delegate to the National Fire Protection Association.

AFTERNOON SESSION.

This session was devoted to a symposium on the "Chicago Drainage Canal Case." The subject was opened by Dr. W. P. Mason, who, also, presented a paper concerning his testimony in the case. Mr. John W. Hill presented a paper entitled "The Chicago Drainage Canal in the United States Courts," Mr. Robert Spurr Weston one entitled "Self Purification of the Mississippi River During the Latter Part of its Course." Professor T. J. Burrill gave an abstract of his testimony in a paper. Papers were also read by Professors Gardner S. Williams, E. O. Jordan—"The Natural Purification of Streams"—Adolph Gehrmann and H. L. Russell.

The subject was orally discussed by Messrs. Rudolph Hering, Geo. C. Whipple, Geo. W. Fuller, Allen Hazen, and Professors Erastus G. Smith and Leonard P. Kinnicutt.

Wednesday evening was spent in a "Trip to Wonderland," under the auspices and guidance of the Local Committee.

THURSDAY, JULY 12TH, 1906.

MORNING SESSION.

The following papers were read and discussed at this session:

1. Copper Sulphate Results, by Mr. James M. Caird.

This paper was discussed by Mr. T. W. Davy, after which discussion was postponed till another paper on a kindred subject was read and the discussion on them was then had jointly.

2. Disinfection as a Means of Water Purification, by Mr. George C. Whipple. The two papers were then discussed by Professors Mason and Kinnicutt, and Messrs. Clemens Herschel, P. A. Maignen, F. A. W. Davis, J. M. Diven and F. L. Fuller.

3. Increasing the Capacity of the Hackensack Water Company's System by Introducing a Relay Pumping Station, as Compared with Cost of Building a New Force Main, by D. W. French.

4. Boiler Plant Economy, by Prof. C. H. Hurd.

5. Notes on Comparative Efficiency of Cast Iron and Riveted Pipe, by Mr. L. J. LeConte.

Dr. George T. Moore and Mr. Karl C. Kellerman were introduced to the convention by Mr. Dabney H. Maury, who was in the chair at this session, and Dr. Moore briefly addressed the convention.

AFTERNOON AND EVENING.

In the afternoon a trip down the harbor was taken on the invitation of the City of Boston, and in the evening the ladies and such of the men as chose, attended the theatre as guests of the Local Committee. The balance of the men were the guests of the Committee at a "Stag" entertainment.

JULY 13TH, 1906.

MORNING SESSION.

Five papers were presented at this session, as follows:

1. Expanding Water Supply Systems, by Mr. J. T. Fanning.

In Mr. Fanning's absence this paper was read by title and was discussed by Messrs. Chas. A. Hague and H. F. Dunham.

2. The Growth of the Pumping Station, by Mr. Chas. A. Hague. Discussion by Messrs. D. H. Maury, H. F. Dunham, F. A. W. Davis, Henry Crowther and D. W. French.

3. Pump Slippage, by Mr. Alba L. Holmes.

Mr. Holmes having been called away this paper was presented by the Secretary and discussed by Messrs. William Perry and C. A. Hague.

4. The Simplex Water Meter, by Mr. J. W. Ledoux.

5. A New Hydraulic Unit, by Prof. D. W. Mead.

AFTERNOON SESSION.

The Local Committee provided a drive to the Country Club for the ladies, and a lunch at the club.

Three papers were presented as follows:

1. A Retrospect of an Arbitration on the Value of a Water Works, by Mr. Albert H. Wehr. Discussion by Messrs. Kenneth Allen, S. J. Rosamond, Owen T. Smith, Martin Prenter, J. M. Caird, Samuel Taylor and Arthur Reimer.

2. Some Interesting Facts Regarding the Great Earthquake of April 18th, 1906, by Mr. L. J. Le Conte. A descriptive paper which was not discussed.

3. Protection of Meter Register, by C. E. Loetzer. Discussed by Messrs. Phil Carlin, F. L. Fuller, M. L. Worrell and W. Volkhardt.

After the reading of these papers the Question Box was taken up and occupied the balance of the session.

EVENING SESSION.

A paper by Mr. F. L. Hand, descriptive of the Philadelphia High Pressure Water Works, was presented, followed by two papers illustrated with lantern slides.

1. Cheeseman Dam, by George T. Prince. In the absence of the author this paper was presented by the Secretary, the views being shown and described.

2. Description of The Metropolitan Water Works, by Mr. Dexter Brackett. A large number of views were shown and described by Mr. Brackett, many of them will be published in the proceedings.

SATURDAY, JULY 14TH, 1906.

The entire day was devoted to sight seeing, two trips having been arranged by the Local Committee, one to Lexington, the other to the Wachusett Dam, where a lunch was served.

At a meeting called to order by the President at Wachusett Dam, the convention, on motion duly made and seconded, was adjourned.

J. M. DIVEN.
Secretary.

OBITUARY

The following members of the association died since the last convention:

Past President, William Ryle

J. B. Powers

H. H. Laing

Charles Hood

John Anderson

J. J. R. Croes

EXHIBITS.

The spacious entrance hall and several rooms in the Rogers Building, Massachusetts Institute of Technology, were fitted up in an attractive and convenient manner for the exhibition of water works appliances; and the following associate members of the Association availed themselves of the privilege, viz:

Joseph T. Ryerson & Son displayed a brass model of their well known boiler, arranged with glass man hole and hand hole plates, to show the operation clearly; the model was under steam pressure, the heat being furnished by electricity.

The Ross Valve Co. showed a model of their feed water heater; also, pressure regulators and valves.

Lead Lined Iron Pipe Co., samples of lead and tin lined iron pipe and fittings.

Pittsburg Meter Co., a large and beautifully arranged display of meters. Some of the meters were in section, showing perfectly the working parts. Their "Eureka" current meter was exhibited for the first time.

R. D. Wood & Co., several fine cuts of Mathew Fire Hydrants, also photographs, neatly framed, of other appliances and machinery manufactured by them.

A. P. Smith Mfg. Co., one of their large tapping machines, doing actual work on a section of cast iron pipe; a special valve, showing a new attachment recently brought out by them; also, small tapping machines and a full line of water works brass goods.

Hersey Manufacturing Co., a display of water meters on a unique and beautiful display stand. They also showed a Detector Meter, and meters in section and in glass cases, also, meter boxes.

Neptune Meter Co., meter boxes and a full line of their water meters. They also showed a large sized current meter, Trident Crest, cut open displaying the working parts. A notable feature of this display was a glass meter connected up with the water supply of the building and in operation, the glass case showing distinctly the workings of the meter.

Glauber Brass Works, a very large display of brass goods, all tastefully arranged, and comprising about every thing in the water works brass goods line.

Buffalo Meter Co., a full display of the disk water meters manufactured by them.

Hays Manufacturing Co., brass goods, service boxes, lead flange connections, etc., all displayed on a beautiful stand.

Allis-Chalmers Co., beautiful framed drawings of pumping engines, also, for distribution, fine catalogues.

Union Water Meter Co., a display of water meters, also, some fine cuts of meters. In addition to the meter exhibit they showed a fine line of water works brass goods, and a pressure regulating valve.

Pitometer Co., a water waste detecting devise attached to pipes and in working order.

Addressograph Co., an addressograph in working order and making out water bills. The young lady in attendance very ably demonstrated the advantages of the addressograph in the water works office, and made up address stamps for members on request.

The Fairbanks Company, a full sized fire hydrant, cut open to display working parts, also, an aluminum model of a fire hydrant. They also had a fine display of gate valves manufactured by them, and a number of large cuts very elegantly and tastefully displayed, making on the whole a beautiful exhibit.

East Jersey Pipe Co., samples of lock-joint riveted pipe, also photographs and catalogues.

Safety Meter Lock Co., display of meter seals shown on plush covered board.

National Meter Co., their full line of meters in several sizes, also photographs of meters and other appliances manufactured by them.

Walworth Manufacturing Co., a notable display of fine tools, also brass goods and Hall Tapping Machine.

Henry R. Worthington, large assortment of water meters.

Water Works Equipment Co., machine for large connections, lead jointers, etc., also samples of cuts from thin pipe made with their tapping machine.

Thomson Meter Co., their usual display of water meters.

Excelsior Wooden Pipe Co., photographs of pipe, and a very complete catalogue, containing much useful information.

Modern Iron Works, stop cock boxes, displayed on a most

ingenious display stand made of iron pipe and fittings.

H. Mueller Mfg. Co., their usual fine display of a complete line of water works brass goods, also of tools, calking tools, stocks, dies, etc.

Chapman Valve Mfg. Co., a fine large view of their plant at Indian Orchard, Mass., and a number of framed views of valves.

Probably the most important exhibit and the one of the greatest interest—attracting the most attention—was the SANITARY SCIENCE EXHIBIT, made for the benefit of the Association by the Massachusetts Institute of Technology. This exhibit was in the Library of the Rogers Building and was one of the finest and most complete exhibitions of the kind ever made. To properly describe it would require a book, rather than the few lines allowed in our proceedings. To water works men it was a most interesting and instructive display, one that has put the Association under a great debt of gratitude to the Massachusetts Institute of Technology.

Another showing out of the ordinary, was that of an ancient fire engine made by Mr. William Perry, of Montreal. A cut of the engine is shown below, together with a history of it by Mr. Perry.

FIRE ENGINE USED IN GREAT LONDON FIRE, 1660.

The necessity for some measures being taken to guard against the destruction of property by fire must have been felt from the very earliest years of civilzation in this country (in London, England) but such attention as our ancestors seem to have devoted to the subject was rather towards preventing fires, and it is only of comparatively late years that any efforts have been made in the direction of extinguishing them.

London may be taken as an instance of this neglect. Considering its enormous population and boundless wealth, it can scarcely be believed that until the year 1866, or exactly 200 years after the Great Fire of London, no public fire brigade had been organized, and this great and pressing want had only been supplied by private and commercial enterprise.

At a very early period there were certain primitive rules for

the protection of property from fire, and for preventing the fires from spreading, but no really important measures were adopted till after the fire of 1666.

The great danger to which the city was then exposed seems to have opened the eyes of the people, and orders were issued that ladders and buckets should be kept for extinguishing purposes in different parts of London.

The catastrophe of the Great London Fire of 1666 seems

FIRE ENGINE OF 1666.

to have awakened the authorities to the fact that the system of buckets, although it possessed that great essential of fire appliances, simplicity, was not quite so effective in its working as was desirable, and accordingly the inventive genius of the age was set to work to devise some method of directing a more continuous and at the same time concentrated stream of water against the flames.

In a very short time the first step towards the modern fire

engine had been made, in the form of a large syringe, of which pattern an Act of Parliament of Charles II's reign, ordained that at least one should be kept at hand in every ward of the city, and worked in case of need by the respective aldermen.

The appearance of this syringe is shown in the accompanying illustration. It consisted of a large cylinder, about three feet in length, with a long nozzle projecting from one end, the whole body of the instrument resembling in some degree a magnified wine bottle, with the difference that at about a quarter of the distance from what would be the base of the shoulder of the bottle, two semi-circular handles were attached, one at each side. Inside this cylinder a piston was worked up and down by means of a piston-rod passing out through the opposite extremity, and the outer end of this rod was enlarged by a round metal knob or plate. It was perhaps, in this enlargement that the chief claim to originality on the part of the invention lay.

Syringes had been known before, though these were certainly constructed on a larger scale than was usual; but there were peculiar necessities attached to the working of these in question, and the inventor is entitled to credit for his ingenuity in adapting them to these necessities. The syringe was filled in the ordinary manner, and then the manipulator had to take hold of the handles, one in each hand, and pressing the enlarged head of the piston-rod firmly against his stomach, draw the handles steadily towards him, at the same time turning the nozzle towards the flames.

Former experience had shown, if not actually in the case of working syringes, at any rate in other phases of human existence, that a sharp pressure against one particular point of the body is apt to be painful, whereas if the surface over which the pressure extends is enlarged, it is very often not even uncomfortable. Having consideration for this, the knob at the head of the piston rod was added, so that the aldermanic tambour might in no way be inconvenienced in the exercise of its owner's statutory duties.

In all probability, however, though we are not told for certain, the civic dignitaries might depute these duties to some person of inferior grade, only being held responsible for their

fulfilment, in the same way that the sheriffs have from time immemorial been permitted to carry out the more unpleasant requirements of their office by proxy. But if, as may have been, it occasionally happened that such substitute was not easily obtainable, as in the case of an early call before the inevitable crowd had had time to assemble, the sight of a heroic body of aldermen encircling the fire, each one armed with his syringe, and each in turn discharging his stream in the prescribed manner against the flames, must have been one calculated to excite the admiration and respect of all who might have the good fortune to arrive on the scene in time to behold it.

This is a simple historical record handed down in due course, and if it seems in any way humorous it must itself bear the consequences. No disrespect or ridicule is intended by the recital, on the contrary, every credit is given to the worthy civic dignitaries who had the courage to attack a formidable enemy with weapons which now appear inadequate; and, after all, it is quite probable that coaches and many other appliances of those early days would raise a smile if contrasted with the luxurious and elaborate mechanisms of the present time.

LIST OF ATTENDANTS AT THE TWENTY-SIXTH ANNUAL CONVENTION.

ACTIVE MEMBERS.

Adkins, B. C., Water Commissioner, St. Louis, Mo.
Affleck, John A., Water Commissioner, Harrisburg, Pa.
Ahern, John T., Superintendent Water Works, Nashville, Tenn.
Amsbary, F. C., Manager Water Works, Champaign, Ill.
Anderson, J. F., Meter Superintendent, Kansas City, Mo.
Anderson, L. W., City Engineer, Grand Rapids, Mich.
Baker, M. N., Engineering News, New York, N. Y.
Bancroft, Lewis M., Superintendent Water Works, Reading, Mass.
Barbour, F. L., Civil Engineer, Boston, Mass.
Bartow, Edward, Director State Water Survey, Urbana, Ill.
Bassett, Geo. B., Civil Engineer, Buffalo, N. Y.
Bauman, C. V., Water Commissioner, Newark, N. J.
Beardsley, H. M., Elmira, N. Y.
Beardsley, Jos. C., Cleveland, O.
Blake, Edmund M., Civil Engineer, Boston, Mass.
Bolling, Chas. E., Superintendent Water Works, Richmond, Va.
Bolton, Channing M., Civil Engineer, Charlottesville, Va.
Bond, Joseph A., Civil Engineer, Wilmington, Del.
Brackett, Dexter, Engineer, Boston, Mass.
Brown, C. Arthur, Sanitary Engineer, Lorain, O.
Brown, Calvin S., Water Commissioner, Chicago, Ill.
Brown, D. A., Official Stenographer and Reporter, Cincinnati, O.
Bruen, G. E., National Fire Protection Association, New York, N. Y.
Bugbee, A., Trenton, N. J.
Caird, James M., Chemist, Troy, N. Y.
Caldwell, Jas. H., Troy, N. Y.
Calpins, Willis N., Chicago, Ill.
Campbell, Chas. H., Atlanta, Ga.
Carlin, Phil, Superintendent, Sioux City, Iowa.
Carter, C. D., Superintendent, Charlottesville, Va.
Cauldfield, John, Secretary Water Board, St. Paul, Minn.
Chisolm, E. N., Jr., City Engineer, Columbia, S. C.
Conard, W. R., Insurance, Burlington, N. J.
Connor, F. J., Superintendent Water Works, Faribault, Minn.
Cook, John H., Hydraulic Eng. E. Jersey Water Co., Paterson, N. J.
Davis, F. A. W., President Water Company, Indianapolis, Ind.
Davey, T. W., Superintendent, Middletown, N. Y.
Deignan, John E., New York, N. Y.
Dill, H. A., Superintendent, Richmond, Ind.
Diven, J. M., Superintendent, Charleston, S. C.
Donahue, J. P., Secretary Water Co., Davenport, Iowa.
Dow, A. R., Superintendent, Salem, Ohio.
Drake, Chester F., Water Co., Pittsburg, Pa.
Dunham, H. F., Engineer, New York, N. Y.
Durlin, Willis B., Water Commissioner, Erie, Pa.
Eggers, A. F., Water Commissioner, Newark, N. J.
Elbert, Edward, Water Commissioner, Reading, Pa.
Ellis, R. E., Superintendent, Jacksonville, Fla.
Ellsworth, E. A., Civil Engineer, Holyoke, Mass.
Ellwood, O., Secretary, London, Ont.
Evans, Jas. R., Chemist, Pottstown, Pa.
Felix, Geo. H., President, Reading, Pa.
Fenn, Chas. W., Consulting Engineer, Portland, Me.
Folwell, A. Prescott, Easton, Pa.

Frailey, E. F., Superintendent, Lancaster, Pa.
French, A. N., Superintendent, Hyde Park, Mass.
French, D. W., Superintendent, Weehawken, N. J.
French, E. V., Boston, Mass.
Fuller, Geo. W., Civil Engineer, New York, N. Y.
Gailey, S. A., Superintendent, Altoona, Pa.
Gallagher, J. F., Superintendent, Kingston, N. Y.
Gannon, Thos. W., Superintendent, Cairo, Ill.
Getchell, Wm. B., City Engineer, Augusta, Me.
Glazier, W. L., Superintendent, Newport, Ky.
Glover, Albert S., Secretary Hersey Manufacturing Co., Boston, Mass.
Gray, H. B., Registrar Water Works, Minneapolis, Minn.
Griswold, F. M., New York, N. Y.
Hague, C. A., Consulting Engineer, New York, N. Y.
Harbster, M., Water Commissioner, Reading, Pa.
Hazen, Allen, Civil Engineer, New York, N. Y.
Heim, John B., Superintendent, Madison, Wis.
Hering, Rudolph, New York, N. Y.
Herschel, Clemens, Hydraulic Engineer, New York, N. Y.
Hibbeler, H. D., Washington, Mo.
Hillabrandt, Lucian, Superintendent, Johnstown, N. Y.
Hines, F. L. Superintendent, Salt Lake City, Utah.
Hollingsworth, Robt., Chief Engineer, Camden, N. J.
Holly, Ira A., Engineer, New York, N. Y.
Holmes, Alba L., Grand Rapids, Mich.
Houston, George, Kalamazoo, Mich.
Huth, Frank, Nazareth, Pa.
Jackson, Robt. A., Superintendent, Norristown, Pa.
Keeler, H. E., President Water Co., Chicago, Ill.
Kelley, Jno. C., President Water Co., New York, N. Y.
Kelley, M. R., Chief Engineer, Dayton, Ohio.
Kellogg, R. M., Superintendent Water Co., Metuchen, N. J.
Kennedy, Geo. G., Superintendent Water Works, Harrisburg, Pa.
Klingburg, W., Civil Engineer, Kingston, N. Y.
Knudson, A. A., New York, N. Y.
Kuichling, E., Consulting Engineer, New York, N. Y.
Latta, L. M., General Manager, Akron, O.
Leighton, M. O., U. S. Geological Survey, Washington, D. C.
Leisen, Theo. A., Chief Engineer Water Department, Wilmington, Del.
Litterer, Fred, Chief Engineer, Decatur, Ill.
Little, B. C., Superintendent Water Works, Rochester, N. Y.
Lochridge, Elbert E., Engineer, Quincy, Mass.
Locke, J. W., Assistant Superintendent, Brockton, Mass.
Loetzer, C. E., Superintendent Water Works, Sayre, Pa.
Loomis, E. L., Superintendent Water Works, Valparaiso, Ind.
Lord, Harry A., Superintendent Water Works, Ogdensburg, N. Y.
Lyon, Harry L. W., Commissioner, Buffalo, N. Y.
McAlpine, A. H., Gen. Western Mgr. Hersey Mfg. Co., Columbus, O.
McArthur, Arthur, Superintendent Water Works, Dubuque, Iowa.
McCarthy, Daniel B., Superintendent Water Works, Waterford, N. Y.
McDargh, H. J., Engineer, Dayton, Ohio.
MacGonigle, J. N., Superintendent Water Works, Miami, Fla.
Maignen, P. A., Filtration Engineer, Philadelphia, Pa.
Manville, F. D., Local Manager, Newport News, Va.
Marple, Wm. M., Chief Engineer, Scranton, Pa.
Mason, W. P., Troy, N. Y.
Mather, Edmund, Commissioner, Harrisburg, Pa.
Maury, Dabney H., Consulting Engineer, Peoria, Ill.
Mercer, E. A., Superintendent Water Works, West Chester, Pa.

Meyers, A. H., Superintendent Water Co., Columbia, Pa.
Milligan, R. E., New York, N. Y.
Milne, Alex., Superintendent Water Works, St. Catharines, Ont.
Monfort, W. F., Chemist, St. Louis, Mo.
Monroe, H. G., Superintendent Water Works, Pontiac, Mich.
Moore, Jno. M., Engineer and Superintendent, London, Ont.
Morris, J. T., New York, N. Y.
Mulhall, Jno. F. J., Boston, Mass.
Nourse, H. O., Superintendent, Chicago, Ill.
Nuebling, Emil L., Superintendent and Engineer, Reading, Pa.
Ohliger, L. B., Superintendent Water Works, Canton, Ohio.
O'Shaughnessy, Jerry, Superintendent, Columbus, Ohio.
Patton, W. A., Catlettsburg, Ky.
Peck, Jno. W., Superintendent, Evansville, Ind.
Perry, Wm., Hdyraulic Engineer, Montreal, Can.
Phillips, Geo. H., Mechanical Engineer, Newark, N. J.
Poetsch, Chas. T., City Engineer, Milwaukee, Wis.
Potts, Clyde, Civil Engineer, New York, N. Y.
Prenter, Martin, General Manager Water Co., Pittsburg, Pa.
Prentice, Allen T., R. D. Wood & Co., Chicago, Ill.
Randolph, W. C. N., Jr., Superintendent, Lynchburg, Va.
Rapp, W. M., Superintendent, Atlanta, Ga.
Reimer, Arthur A., Superintendent, East Orange, N. J.
Robertson, Geo. H., Superintendent, Yarmouth, N. S.
Rosamond, S. J., Superintendent, Fort Smith, Ark.
Sando, Will J., Milwaukee, Wis.
Sawyer, J. T., President Water Co., Waverly, N. Y.
Schwertferger, Wm., Secretary, Wheeling, W. Va.
Sears, Walter, Chief Eng. Aqueduct Commission, New York, N. Y.
Shaw, Benj. F., Water Commissioner, Wilmington, Del.
Sheppard, Jas. H., Monongahela City, Pa.
Shepperd, F. W., Fire and Water Engineering, New York, N. Y.
Sherrerd, M. R., Chief Engineer, Newark, N. J.
Sidelinger, Geo. B., Danville, Ill.
Smith, Anthony P., Hydraulic Engineer, Newark, N. J.
Smith, J. Waldo, Chief Engineer Board Water Supply, New York, N. Y.
Smith, Owen T., Superintendent and Secretary, Freeport, Ill.
Snell, Jas. R., Superintendent, Amsterdam, N. Y.
Snell, Geo. H., Superintendent Water Works, Attleboro, Mass.
Soper, Geo. A., Consulting Engineer, New York, N. Y.
Sprenkel, John F., General Manager, York, Pa.
Staples, Geo. T., Superintendent, Dedham, Mass.
Sterling, Joe. C., Superintendent Water Works, Monroe, Mich.
Strauss, Nathan, President Water Works, Ashland, Ohio.
Taylor, John T., General Manager, Beaver Falls, Pa.
Taylor, S. A., Pittsburg, Pa.
Thomas, Robt. J., Superintendent, Lowell, Mass.
Tighe, Jas. L., City Engineer, Holyoke, Mass.
Todd, Wm., Superintendent, Austin, Minn.
Travis, Isaac N., Superintendent, Orange, N. J.
Tucker, A. A., Superintendent Mains, Memphis, Tenn.
Tuttle, Arthur S., New York, N. Y.
Van Gilder, L., Engineer and Supt. Water Dept., Atlantic City, N. J.
Veach, W. A., Newark, Ohio.
Warde, John S., Superintendent Water Co., Staten Island, N. Y.
Watkins, Thomas, General Foreman, Johnstown, Pa.
Wehr, Albert, Secretary and Treasurer, Baltimore, Md.
Welling, Robert, Superintendent Water Works, Covington, Ky.
Weston, Robt. Spurr, Boston, Mass.

Wheeler, Sam, Superintendent Water Co., Ashland, Wis.
Whipple, Geo. C., New York, N. Y.
Whitney, Geo. F., East Orange, N. J.
Wiles, C. W., Superintendent, Delaware, Ohio.
Williams, Gardner S., Civil Engineer, Ann Arbor, Mich.
Wirt, R. D., Philadelphia, Pa.
Woodburn, Wm. F., R. D. Wood & Co., Philadelphia, Pa.
Woods, L. R., Superintendent, Everett, Mass.
Woodruff, Timothy, Superintendent, Bridgeton, N. J.
Worrell, M. L., Secretary and Treasurer, Selma, Ala.
Young, T. L., Superintendent, Chester, W. Va.

ASSOCIATE MEMBERS.

Adams, F. E., Secretary Coffin Valve Co., Boston, Mass.
Anderson, L. P., Union Water Meter Co., Richmond, Va.
Arnold, V. E., Pittsburg Meter Co., Scranton, Pa.
Bailey, G. H., Jr., National Meter Co., Pittsburg, Pa.
Baker, Shirley, Excelsior Wooden Pipe Co., New York, N. Y.
Barnard, Leon S., Hersey Manufacturing Co., New York, N. Y.
Bartlett, W. E., Penna. Salt Manufacturing Co., Philadelphia, Pa.
Bates, Fred S., Rensselaer Manufacturing Co., Troy, N. Y.
Beach, C. G., Central Foundry Co., New York, N. Y.
Beach, C. L., Builders Iron Foundry, Providence, R. I.
Blake, E. M., Pitometer Co., New York, N. Y.
Booth, L. M., The L. M. Booth Co., New York, N. Y.
Bradley, F. J., National Meter Co., Chicago, Ill.
Brokaw, John H., Jr., Water Commissioner, Trenton, N. J.
Brown, C. L., Rensselaer Manufacturing Co., Worcester, Mass.
Brown, E. F., Neptune Meter Co., New York, N. Y.
Burke, G. H., International Steam Pump Co., Boston, Mass.
Caldwell, Geo. A., H. Mueller Manufacturing Co., Boston, Mass.
Caldwell, Jas. H., V. P. Ludlow Valve Manufacturing Co., Troy, N. Y.
Camiel, L. H., Cancos Manufacturing Co., Philadelphia, Pa.
Carr, G. H., H. R. Worthington, Chicago, Ill.
Carter, Jas. S., The Fairbanks Co., Lynn, Mass.
Cetti, W. S., Thomson Meter Co., Brooklyn, N. Y.
Chellew, W. J., Buffalo Meter Co., Buffalo, N. Y.
Clifford, T. C., Pittsburg Meter Co., Pittsburg, Pa.
Collins, H. W., A. P. Smith Manufacturing Co., Detroit, Mich.
Corbett, J. T., J. T. Ryerson & Son, Chicago, Ill.
Corse, A. P., Neptune Meter Co., Atlanta, Ga.
Costello, Geo. M., Cancos Manufacturing Co., Philadelphia, Pa.
Coulters, Albert B., Builders Iron Foundry, Providence, R. I.
Cox, W. E., National Meter Co., New York, N. Y.
Crowther, Henry, R. D. Wood & Co., Philadelphia, Pa.
Davis, J. Hans, Pittsburg Meter Co., Pittsburg, Pa.
Dean, Mark, Central Foundry Co., New York, N. Y.
Deericks, J. G., American Steel & Wire Co., New York, N. Y.
Deering, C. M., Allis-Chalmers Co., Boston, Mass.
Doran, H. F., Neptune Meter Co., Chicago, Ill.
Dwyer, Thos. E., Lead Lined Iron Pipe Co., Wakefield, Mass.
Elwell, W. R., N. Y. Continental Jewell Filter Co., New York, N. Y.
Farwell, Austin W., The Fairbanks Co., Boston, Mass.
Faulks, Thos. J., Neptune Meter Co., Boston, Mass.
Fisher, Geo. J., Modern Iron Works, Quincy, Ill.
Ford, Thomas, Bourbon Copper & Brass Works, Cincinnati, O.
Francis, Chas. S., National Meter Co., Chicago, Ill.
Gamon, Ernest, Neptune Meter Co., New York, N. Y.

Gates, S. P., Fairbanks Co., Boston, Mass.
Ginder, John, Water Commissioner, Trenton, N. J.
Gould, H. F., Ludlow Valve Manufacturing Co., Troy, N. Y.
Hammon, E. A., Central Foundry Co., New York, N. Y.
Hanks, F. W., Neptune Meter Co., Cleveland, Ohio.
Hall, Frank E., Union Water Meter Co., Worcester, Mass.
Harrison, Sam'l., Henry R. Worthington, New York, N. Y.
Harwood, Chas. F., International Steam Pump Co., Boston, Mass.
Hays, A. D., Pittsburg Meter Co., Pittsburg, Pa.
Hersey, Francis C., Sr., Hersey Manufacturing Co., Boston, Mass.
Hersey, Francis C., Jr., Hersey Manufacturing Co., Boston, Mass.
Hersey, Walter A., Hersey Manufacturing Co., Boston, Mass.
Higley, S. D., Thomson Meter Co., Brooklyn, N. Y.
Holmes, A. G., Pittsburg Meter Co., East Pittsburg, Pa.
Holmes, W. A., Pittsburg Meter Co., Pittsburg, Pa.
Howard, E. G., Coffin Valve Co., Boston, Mass.
Hughes, Edward F., Chapman Valve Mfg. Co., Boston, Mass.
Hurley, J. J., Ellis Ford Manufacturing Co., Detroit, Mich.
Jones, O., Rensselaer Manufacturing Co., Chicago, Ill.
Keefer, Geo. M., Renssalaer Manufacturing Co., Pittsburg, Pa.
Kerney, Jas., Water Commissioner, Trenton, N. J.
King, Edw. P., Union Water Meter Co., Worcester, Mass.
Kinsey, H. H., Neptune Meter Co., Boston, Mass.
Kinsey, J. S., Neptune Meter Co., Boston, Mass.
Lane, Frederick, Wm. B. Merrill & Co., Boston, Mass.
Leavitt, F. A., The Fairbanks Co., Melrose, Mass.
Leopold, H. B., Pittsburg Filter Manufacturing Co., Pittsburg, Pa.
Libby, A. N., Allis-Chalmers Co., Boston, Mass.
Long, J. H., Wm. Tod Co., Youngstown, O.
Lufkin, J. G., National Meter Co., Boston, Mass.
Manning, John W., Water Commissioner, Trenton, N. J.
May, Chas. A., Water Commissioner, Trenton, N. J.
Moore, Chas. B., International Steam Pump Co., Boston, Mass.
Mueller, Fred B., H. Mueller Manufacturing Co., Decatur, Ill.
Mueller, Henry, H. Mueller Manuafacturing Co., Decatur, Ill.
Mull, E. F., Hersey Manufacturing Co., Zanesville, Ohio.
Nagle, T. J., Hays Manufacturing Co., Erie, Pa.
Nevins, Frank W., U. S. Cast Iron Pipe & Fdry Co., New York, N. Y.
Northrop, F. L., Union Water Meter Co., Worcester, Mass.
Northrop, Malan L., Union Water Meter Co., Worcester, Mass.
O'Brien, D. F., A. P. Smith Manufacturing Co., Newark, N. J.
O'Brien, J. F., Fairbanks, Co., New York, N. Y.
Ober, W. N., Allis-Chalmers Co., Boston, Mass.
Otis, G. Frank, Union Water Meter Co., Pasadena, Cal.
Pardee, E. T., Allis-Chalmers Co., Boston, Mass.
Phillips, F. F., General Chemical Co., Boston, Mass.
Pickering, Geo. E., Walworth Manufacturing Co., Boston, Mass.
Pilcher, Arthur C., H. Mueller Manufacturing Co., Springfield, Mass.
Pray, A. J., Secretary Safety Meter Lock Co., Columbus, Ohio.
Price, Wm. T., Board of Public Service, Columbus, Ohio.
Putnam, Hobart H., U. S. Cast Iron Pipe & Fdry. Co., New York, N. Y.
Putnam, H. J., Thomson Meter Co., Detroit, Mich.
Relda, H. E., Glauber Brass Manufacturing Co., Chicago, Ill.
Robinson, F. S., Eddy Valve Co., Waterford, N. Y.
Ross, Wm., Ross Valve Co., Troy, N. Y.
Savage, W. G., U. S. Cast Iron Pipe & Foundry Co., Chicago, Ill.
Schmidt, F. C., Pleuger & Henger Manufacturing Co., St. Louis, Mo.
Schwertferger, Wm., Wheeling, W. Va.
Seagrave, F. S., Hydrant Cut-Off Valve, Detroit, Mich.

Shedd, Edward M., Thompson Meter Co., Somerville, Mass.
Sherwood, Wm. C., Hersey Manufacturing Co., Boston, Mass.
Skirm, Chas. H., Water Commissioner, Trenton, N. J.
Smith, Fred A., Hersey Manufacturing Co., New York, N. Y.
Snow, E. J., Thomson Meter Co., Brooklyn, N. Y.
Stewart, Chas., Neptune Meter Co., Newark, N. J.
Stone, Herbert E., Chapman Valve Mfg. Co., Indian Orchard, Mass.
Strackbien, John W., A. P. Smith Manufacturing Co., Chicago, Ill.
Swaffield, T. G., Pittsburg Meter Co., Columbia, S. C.
Titcomb, E. J., Union Water Meter Co., Worcester, Mass.
Tomes, P. Austin, Atlas Portland Cement Co., New York, N. Y.
Truxal, N. W., Addressograph Co., Boston, Mass.
Van Winkle Water Works Equipment Co., New York, N. Y.
Vaughan, C. A., Neptune Meter Co., Boston, Mass.
Voss, P. J., National Meter Co., Atlanta, Ga.
Warde, John S., Jr., Rensselaer Manufacturing Co., New York, N. Y.
Weaver, A. T., American Steel & Wire Co., Chicago, Ill.
Webber, W. J., Cochrane Chemical Co., Boston, Mass.
Wertz, J. L., Neptune Meter Co., New York, N. Y.
Weston, H. L., Coffin Valve Co., Boston, Mass.
Wetherill, C. M., Neptune Meter Co., Chicago, Ill.
Whitcomb, F. N., A. P. Smith Manufacturing Co., Newark, N. J.
Whitney, Geo. F., President Hudson Contracting Co., New York, N. Y.
Winton, Henry D., Assistant Manager, Hersey Mfg. Co., Boston, Mass.
Wood, R. D., & Co., Philadelphia, Pa.
Young, Chas. H., Water Commissioner, Trenton, N. J.

GUESTS—LADIES.

Mrs. Aley, F. D., Wichita, Kan.
Mrs. Allen, M. L., Boston, Mass.
Mrs. Amsbary, F. C., Champaign, Ill.
Mrs. Austin, L. N., Providence, R. I.
Mrs. Baldwin, Chas. H., Boston, Mass.
Miss Barker, Clara E., Boston, Mass.
Miss Bartlett, Alice G., Boston, Mass.
Mrs. Beardsley, J. C., Cleveland, O.
Mrs. Bickford, H. E., Boston, Mass.
Mrs. Birmingham, J. M., Hartford, Conn.
Mrs. Blake, Edmund M., Brookline, Mass.
Mrs. Bolling, Chas. E., Richmond, Va.
Mrs. Bradley, F. J., Chicago, Ill.
Mrs. Brooks, Edwin C., Cambridge, Mass.
Miss Brooks, Catharine, Boston, Mass.
Mrs. Brown, C. S., Chicago, Ill.
Mrs. Brown, H. A., Boston, Mass.
Mrs. Buchman, J. F., Canton, O.
Miss Bush.
Mrs. Carlin, Phil, Sioux City, Iowa.
Mrs. Carr, Geo. H., Chicago, Ill.
Mrs. Carr., J. M., Chicago, Ill.
Mrs. Chester, E. F., Newton Center, Mass.
Mrs. Clark, E. W., Minneapolis, Minn.
Mrs. Clifford, T. C., Pittsburg, Pa.
Miss Clifford, Lois, Pittsburg, Pa.
Mrs. Close, S. H., Reading, Pa.
Mrs. Collins, H. W., Detroit, Mich.
Miss Collins, Julia, Lawrence, Mass.
Miss Collins, Helen, Lawrence, Mass.

Mrs. Conover, E. E., Auburndale, Mass.
Miss Corbett, Mabel, Chicago, Ill.
Mrs. Cox, W. E., New York, N. Y.
Mrs. Darch, F. J., London, Ont.
Mrs. Dean, Mark, New York, N. Y.
Miss Dean, Marjorie M., New York, N. Y.
Mrs. Deering, C. M., Allston, Mass.
Mrs. Dill, H. A., Richmond, Ind.
Mrs. Dow, D. L., Somerville, Mass.
Mrs. Doyle, John C., Nashville, Tenn.
Mrs. Doyle, John, Nashville, Tenn.
Miss Drake, Cleveland, O.
Mrs. Dunbar, C. D., Salt Lake City, Utah.
Mrs. Ellis, R. N., Jacksonville, Fla.
Mrs. Ellwood, O., London, Ont.
Miss Ellwood, London, Ont.
Mrs. Ellsworth, E. A., Holyoke, Mass.
Mrs. Farnham, Irving T., Newton, Mass.
Mrs. Felix, Geo. H., Reading, Pa.
Mrs. Felton, B. R., Boston, Mass.
Mrs. Ferguson, John N., Boston, Mass.
Miss Flinn, Margaret G., West Roxbury, Mass.
Mrs. Flinn, E. R., West Roxbury, Mass.
Miss Florentine, Boston, Mass.
Mrs. Frailey, E. F., Lancaster, Pa.
Mrs. Frailey, Wm. H., Lancaster, Pa.
Mrs. French, A. N., Hyde Park, Mass.
Mrs. French, D. W., Weehawken, N. J.
Mrs. Fuller, Frank L., Wellesley Hills, Mass.
Mrs. Gage, S. DeM., Lawrence, Mass.
Mrs. Gallagher, John F., Kingston, N. Y.
Mrs. Gannon, Thos. W., Cairo, Ill.
Mrs. Gardner, A. E., Pittsburg, Pa.
Mrs. Gearhardt, F. C., Altoona, Pa.
Miss Gerry, Josephine, Orange, N. J.
Miss Glazier, Mary, Newport, Ky.
Mrs. Glazier, W. L., Newport, Ky.
Miss Goldthwait, Nellie, Marblehead, Mass.
Miss Ham, J. M., Boston, Mass.
Mrs. Hanks, F. W., Cleveland, O.
Mrs. Harbster, M., Reading, Pa.
Mrs. Harrison, Sam'l., Somerville, Mass.
Mrs. Hersey, F. F., Sr., Wellesley, Mass.
Mrs. Hershede, A., Cincinnati, O.
Miss Hodgkins, Marjorie, Malden, Mass.
Mrs. Holly, I. A., New York, N. Y.
Mrs. Holmes, Alba L., Grand Rapids, Mich.
Mrs. Hotsinger, C. E., Memphis, Tenn.
Mrs. Houston, Geo., Kalamazoo, Mich.
Mrs. Howard, J. L., Melrose, Mass.
Mrs. Jackson, Robt. A., Norristown, Pa.
Mrs. Jones, O., Chicago, Ill.
Mrs. Kay, J. W., Milford, Mass.
Mrs. Keeler, H. E., Chicago, Ill.
Miss Keeler, Chicago, Ill.
Mrs. Kelley, John C., New York, N. Y.
Miss Kelley, Josephine, New York, N. Y.
Mrs. Kennedy, Geo. D., Harrisburg, Pa.
Mrs. Kimball, F. C., Boston, Mass.

Miss Kimball, Florence, Boston, Mass.
Mrs. Kimball, J. H., Newton, Mass.
Mrs. Kornfeld, A. E., New York, N. Y.
Mrs. Latta, L. M., Akron, O.
Mrs. Leavitt, F. A., Melrose, Mass.
Miss Leavitt, L. F., Melrose, Mass
Miss Leavitt, Lillian, Somerville, Mass.
Mrs. Lufkin, J. G., Boston, Mass.
Mrs. McAllister, Josaphine, Boston, Mass.
Mrs. McAlpine, A. H., Columbus, O.
Mrs. McCarthy, D. B., Waterford, N. Y.
Mrs. Macksey, H. V., Boston, Mass.
Mrs. Madden, W. M., Evansville, Ind.
Miss Madden, Katherine, Evansville, Ind.
Mrs. Marble, A. D., Lawrence, Mass.
Miss Marble, Marion W., Lawrence, Mass.
Mrs. Meredith, Washington, Cincinnati, O.
Mrs. Martin, Herman, Cambridge, Mass.
Mrs. Merrill, A. S., Bath, Me.
Miss Moffett, Minnie, Boston, Mass..
Mrs. Milligan, Robt. E., New York, N. Y.
Mrs. Miller, H. A., Boston, Mass.
Mrs. Moore, John M., London, Ont.
Mrs. Morton, Newton, Florence, N. J.
Miss Morton, Florence, N. J.
Mrs. Mueller, Henry, Decatur, Ill.
Mrs. Mullhall, Jno. F. J., Boston, Mass.
Miss Mullhall, Marion, Boston, Mass.
Mrs. O'Brien, J. F., New York, N. Y.
Miss O'Brien, Zada, New York, N. Y.
Mrs. Ohliger, L. B., Canton, O.
Miss Pevey, Laura, Somerville, Mass.
Mrs. Peck, J. W., Evansville, Ind.
Miss Peck, Ruth, Evansville, Ind.
Mrs. Pickering, Geo. E., Boston, Mass.
Miss Pollock, Frances, Brooklyn, N. Y.
Mrs. Prenter, M., Pittsburg, Pa.
Mrs. Prentice, Allen T., Chicago, Ill.
Miss, Prentice, E. L., Chicago, Ill.
Mrs. Price, Wm. T., Columbus, O.
Mrs. Procter, E. E., Wakefield, Mass.
Mrs. Putnam, H. J., Detroit, Mich.
Mrs. Rickards, B. R., Boston, Mass.
Miss Roberts, M., Boston, Mass.
Mrs. Rosamond, S. J., Ft. Smith, Ark.
Mrs. Saville, C. M., Malden, Mass.
Miss Seaverns, Hattie, North Scituate, Mass.
Mrs. Shaw, Helen M., Wilmington, Del.
Mrs. Shedd, E. M., Somerville, Mass.
Mrs. Sheppard, J. H., Monongahela City, Pa.
Mrs. Shepperd, F. W., New York, N. Y.
Mrs. Sidelinger, G. B., Boston, Mass.
Mrs. Smith, Fred A., New York, N. Y.
Mrs. Snell, J. R., Amsterdam, N. Y.
Miss Snell, Florence M., Amsterdam, N. Y.
Miss Stein, Kate, Sioux City, Iowa.
Mrs. Stone, Herbert E., Indian Orchard, Mass.
Mrs. Sullivan, T. V., Boston, Mass.
Mrs. Taylor, S. A., Pittsburg, Pa.

Mrs. Thomas, R. J., Lowell, Mass.
Miss Thomas, Mary E., Lowell, Mass.
Mrs. Thompson, Sanford E., Newton Highlands, Mass.
Mrs. Thompson, Mary F., Davenport, Ia.
Mrs. VanWinkle, W. H., Newark, N. J.
Mrs. Veach, W. A., Newark, O.
Miss Walsh, Katherine, Lowell, Mass.
Miss Walsh, Charlotte, Lowell, Mass.
Mrs. Waits, C. A., Boston, Mass.
Mrs. Warde, J. S., Staten Island, N. Y.
Mrs. Webber, W. J., Hyde Park, Mass.
Mrs. Wheeler, Sam, Ashland, Wis.
Miss Wheeler, Ruth, Ashland, Wis.
Mrs. Whitaker, J. H., New York, N. Y.
Miss Williams, Edna, Detroit, Mich.
Mrs. Williams, Gardner, S., Ann Arbor, Mich.
Mrs. Wills, Wirt J., Memphis, Tenn.
Mrs. Wilson, Charles, West Newton, Mass.
Mrs. Winters, F., Boston, Mass.
Mrs. Winton, H. D., Wellesley, Mass.
Miss Wirt, Edith, Philadelphia, Pa.
Mrs. Witherill, C. M., Chicago, Ill.

GUESTS.

Agnew, H. M., North Scituate, Mass.
Agnew, S. A., North Scituate, Mass.
Alexander, Chas. E., Boston Transcript, Boston, Mass.
Aley, F. D., Wichita, Kan.
Allbee, Robert, Bellows Falls, Vt.
Ames, C. M., Brockton, Mass.
Amyot, John A., Toronto, Ont.
Anderson, James F., Boston, Mass.
Austin, L. N., Providence, R. I.
Barnes, Roland D., Bristol, Ct.
Barrow, J. S., Jr., Bridgeport, Ct.
Barrows, H. K., Boston, Mass.
Barton, H., Philadelphia, Pa.
Bartlett, C. H., Boston, Mass.
Batchelder, Geo. W., Worcester, Mass.
Bazan, Chas. R., New York, N. Y.
Berry, F. G., Hartford, Ct.
Bigelow, Jas. T., Marlboro, Mass.
Birmingham, J. M., Hartford, Ct.
Blackwell, V., London, Ont.
Blackmer, A. E., Plymouth, Mass.
Blackmer, Jas. W., Beverly, Mass.
Bowker, Chas. L., Brunswick, Me.
Bradley, H. C., Chicago, Ill.
Breed, C. B., Boston, Mass.
Brett, Geo. M., Boston, Mass.
Brogan, J. A., Lawrence, Mass.
Brooks, E. C., Cambridge, Mass.
Brown, Leroy, Waltham, Mass.
Brown, Marshall L., M.D., Boston, Mass.
Buchman, J. F., Canton, O.
Bueno, Joseph, Everett, Mass.
Burnie, James, Biddeford, Me.
Busch, Francis K., Boston, Mass.

Callahan, J. F., Norwood, Mass.
Cardwell, Hon, Wm., East Orange, N. J.
Carter, Frank H., Boston, Mass.
Chadbourne, E. J., Wollaston, Mass.
Chase, John C., Derry, N. H.
Chase, Horace H., Boston, Mass.
Childs, Charles E., Somerville, Mass.
Churchill, Percival M., Boston, Mass.
Clark, E. W., Minneapolis, Minn.
Clark, H. B., Chicago, Ill.
Clark, H. W., Boston, Mass.
Close, S. H., Reading, Pa.
Coolidge, J. Randolph, Boston, Mass.
Collins, T. Addison, Lawrence, Mass.
Collins, M. F., Lawrence, Mass.
Conover, E. E., Auburndale, Mass.
Cook, H. G., St. Paul, Minn.
Coppins, W. P., Boston, Mass.
Crandall, George K., New London, Ct.
Crawford, J. W., Lowell, Mass.
Cripps, Geo. E., Rochester, N. Y.
Crowell, Geo. E., Brattleboro, Vt.
Cullen, Geo. T., Malden, Mass.
Cutler, Wm. H., Cambridge, Mass.
Darch, F. J., London, Ont.
Denison, John P., Chicago, Ill.
Dillon, M. F., Binghamton, N. Y.
Dilts, Henry I., New York, N. Y.
Doane, A. O., Boston, Mass.
Dow, D. L., Somerville, Mass.
Doyle, John C., Nashville, Tenn.
Dunbar, D. C., Salt Lake City, Utah.
Dyer, E. R., Portland, Me.
Farnham, Irving T., Newton, Mass.
Farnum, L. N., Boston, Mass.
Felton, B. R., Boston, Mass.
Ferguson, John N., Boston, Mass.
Field, E. L., Northfield, Vt.
Finneran, Geo. H., Boston, Mass.
Fiske, H. F., Boston, Mass.
Fitzgerald, Desmond, Brookline, Mass.
Flinn, Richard J., West Roxbury, Mass.
Flynn, John H., Boston, Mass.
Forbes, F. F., Brookline, Mass.
Fortney, Chas. S., Ashland, O.
Foss, W. E., Boston, Mass.
Frailey, Wm. H., Lancaster, Pa.
Freshney, Samuel A., Grand Rapids, Mich.
Fuller, Frank L., Boston, Mass.
Furbush, Geo. W., Waltham, Mass.
Gage, S. DeM., Lawrence, Mass.
Gailey, S. A., Altoona, Pa.
Gearhardt, F. C., Altoona, Pa.
Gilbert, A. W., Hartford, Ct.
Gilderson, D. H., Haverhill, Mass.
Gilmour, Wm., Boston, Mass.
Goldthwait, Wm. J., Marblehead, Mass.
Gray, Henry F., Columbus, O.
Gunther, Frank H.

Goodnough, X. H., Boston, Mass.
Hale, Richard A., Lawrence, Mass.
Harrison, J. F., Jackson, Mich.
Hawkes, George W., Portland, Me.
Hefferman, David A., Milton, Mass.
Herschede, Anthony, Cincinnati, O.
Hodgdon, Frank W., Boston, Mass.
Holden, Horace G., Nashua, N. H.
Holmes, C. R., Minneapolis, Minn.
Holmes, J. Albert, Somerville, Mass.
Howard, J. L., Melrose, Mass.
Howe, Alfred F., New York, N. Y.
Howe, Freeland, Jr., Norway, Me.
Hubbard, T. T., Milwaukee, Wis.
Insull, F. W., Chicago, Ill.
Jackson, M. L., Jr., Boston, Mass.
Jackson, William, Boston, Mass.
Johnson, William S., Boston, Mass.
Jones, James A., Stoneham, Mass.
Kay, J. W., Milford, Mass.
Keeler, J. S., Boston, Mass.
Kellerman, Karl F., Washington, D. C.
Kelley, John, Braintree, Mass.
Kent, Edmund W., Woonsocket, R. I.
Kent, Willard, Narragansett Pier, R. I.
Killam, Jas. W., Boston, Mass.
Kimball, J. H., Newton, Mass.
King, Geo. A., Taunton, Mass.
King, Peter, Mattapan, Mass.
Kingman, Horace, Brockton, Mass.
Kinnicutt, Leonard P., Worcester, Mass.
Kornfeld, A. E., New York, N. Y.
Kredee, Wm. H., Johnstown, Pa.
Kuhn, S. F., Columbus, O.
Kunhardt, L. H., Boston, Mass.
Larned, E. S., Boston, Mass.
Larned, H. A., Oxford, Mass.
Lenhart, Geo. S., Atlantic City, N. J.
Lennon, James P., Boston, Mass.
Lincoln, James L., Boston, Mass.
Loher, E., Leominster, Mass.
Loomis, J. L., Valparaiso, Ind.
Lyman, James W., Pittsfield, Mass.
Lynch, J. W., Boston, Mass.
McInnes, F. A., Boston, Mass.
McKenzie, T. H., Hartford, Ct.
McLaskey, H. G., Minneapolis, Minn.
McNulty, M. J., Lawrence, Mass.
Maybury, W. E., Braintree, Mass.
Madden, W. M., Evansville, Ind.
Mann, Geo. E., Woodsville, N. H.
Manville, G. E., Boston, Mass.
Marble, Arthur D., Lawrence, Mass.
Marsden, A. H., Lawrence, Mass.
Martin, Herman, Salt Lake City, Utah.
Martin, T. P., West Springfield, Mass.
Marx, W. S., Cincinnati, O.
Meredith, Washington, Cincinnati, O.
Merrill, A. S., Bath, Me.

Merrill, Frank E., Somerville, Mass.
Miller, Hiram A., Boston, Mass.
Monteverde, Peter, Pittsburg, Pa.
Moore, Geo. T., Philadelphia, Pa.
Moore, J. Clare, London, Ont.
Morse, E. P., Boston, Mass.
Murphy, John W., Malden, Mass.
Norton, Joseph J., Boston, Mass.
Pierce, Thos. A., East Greenwich, R. I.
Perkins, J. B., Revere, Mass.
Philps, Earle B., Boston, Mass.
Pickering, Howard B., Boston, Mass.
Plaisted, Arthur, Boston, Mass.
Pollock, C. D., Brooklyn, N. Y.
Pratt, Chas. E., Portland, Ct.
Price, Wm. Herbert, Columbus, O.
Proctor, E. E., Wakefield, Mass.
Proctor, R. F., New York, N. Y.
Randles, Chas. D., Ogdensburg, N. Y.
Regan, Dennis F., Wakefield, Mass.
Rickards, B. R., Boston, Mass.
Rinker, Andrew, Minneapolis, Minn.
Robinson, Leonard B., Concord, Mass.
Rosnosky, Isaac, Boston, Mass.
Royce, H. E., Brookline, Mass.
Rudy, E. H., Scranton, Pa.
Saville, C. M., Malden, Mass.
Sanborn, Morton F., Boston, Mass.
Scannell, J. J., Boston, Mass.
Schoonmaker, F. L., Minneapolis, Minn.
Scranton, Worthington, Scranton, Pa.
Sedgwick, Wm. T., Boston, Mass.
Sibley, E. W., Boston, Mass.
Sinclair, M. A., Bangor, Me.
Slack, Francis H., Boston, Mass.
Slatterlee, W. E., Minneapolis, Minn.
Somers, Wm. H., East Orange, N. J.
Souder, R. F., Atlantic City, N. J.
Sparks, H. T., Brewer, Me.
Stacy, Geo. A., Marlboro, Mass.
Stevens, F. E., Columbus, O.
Stiles, J. D., Boston, Mass.
Stodder, W. F., New York, N. Y.
Sullivan, T. V., Boston, Mass.
Taft, David N., Oxford, Mass.
Thomas, Harry L., Hingham, Mass.
Thomas, W. T., Hingham, Mass.
Thompson, Sanford E., Newton Highlands, Mass.
Tilden, J. A., Jr., Boston, Mass.
Tower, D. N., Cohasset, Mass.
VanWinkle, Walter H., Newark, N. J.
Walsh, George H., Pittsfield, Mass.
Warren, C. O., Boston, Mass.
Wason, Leonard C., Boston, Mass.
Welch, Wm. J., Boston, Mass.
Whaley, L. A., Attleboro, Mass.
Wheeler, Robert, Ashland, Wis.
Whitney, John C., West Newton, Mass.
Wilde, Geo. E., Boston, Mass.

Wills, Wirt J., Memphis, Tenn.
Wilson, Chas., West Newton, Mass.
Winslow, C. E. A., Boston, Mass.
Winslow, Frederic I., Boston, Mass.
Winslow, Geo. E., Waltham, Mass.
Winther, Chas. A. G., Detroit, Mich.
Winton, Clifford, Wellesley, Mass.
Wright, Wm. L., Boston, Mass.
Young, J. F., East Liverpool, O.

LIST OF MEMBERS

AMERICAN WATER WORKS ASSOCIATION

*Corporate Active Members.

HONORARY.

	Date of Admission.
BEMENT, R. B. C.	
St. Paul, Minn.	1888
CAMERON, W. L.	
Asst. Claim Agt., City R. R., 26 Sullivan Bldg., Seattle, Wash.	1881
FOSTER, J. F.	
Room 43, 92 La Salle St., Chicago, Ill.	1881
HOLLY, IRA A.	
129 East 59th St., New York City	1881
HOLMAN, M. L.	
1324 Chemical Bldg., St. Louis, Mo.	1881
NAKAJIMA, Y.	
Imperial University, Tokyo, Japan	1887
WATTS, SYLVESTER.	
St. Louis, Mo.	1881

ACTIVE.

ADKINS, B. C.	
Water Comr., 312 City Hall, St. Louis, Mo.	1900
AFFLECK, JOHN A.	
Water Comr., Harrisburg, Pa.	1899
AHERN, JOHN T.	
Supt. Water Works, Nashville, Tenn.	1904
AIKEN, HENRY M.,	
Res. Mgr. Water Co., Knoxville, Tenn.	1904
ALDERMAN, C. L.	
Mgr. Water Co., Big Springs, Texas	1904
ALLIN, T. D., C. E.	
101 E. Walnut St., Pasadena, Cal.	1906
ALTFATHER, W. F.	
Mgr. Water, Light & Ice Co., Weatherford, Tex.	1906
ALVORD, JOHN W.	
Cons. Engr., 1207 Hartford Bldg., Chicago, Ill.	1899
AMSBARY, F. C.	
Mgr. Champagne & Urbana Water Co., Champagne, Ill.	1902

	Date of Admission.
ANDERSON, J. F.	
Meter Supt., 1737 Washington St., Kansas City, Mo....	1903
ANDERSON, L. W.,	
City Engr., Grand Rapids, Mich.....	1901
ANDREWS, LEWIS P.	
Pres. Water & Light Co., Sedalia, Mo.....	1904
ARTINGSTALL, SAMUELL G.	
239 Rialto Bldg., Chicago, Ill.....	1890
BABCOCK, S. E.	
Hydraulic Engr., 54 Mann Bldg., Utica, N. Y.....	1886
BACOT, R. C.	
Insp. Meter Dept., P. O. Box 221, Port Chester, N. Y...	1894
BAIN, ERNEST B.	
Supt. Wake Water Co., Raleigh, N. C.....	1904
BAKER, HORACE S.	
Engr. Water Pipe Extension, Room 317, City Hall, Chicago, Ill.....	1906
BAKER, M. N.	
Assoc. Editor Engineering News, 220 Broadway, New York, N. Y.....	1903
BANCROFT, LEWIS M.	
Supt. Water Works, Reading, Mass.....	1905
BANCROFT, P. T.	
Supt. Water-Works, Rock Island, Ill.....	1903
BARBOUR, FRANK A.	
Hydraulic & Sanitary Engr., 1120 Tremont Bldg., Boston, Mass.	1906
BARKER, W. H.	
Sec. Board of Water-Works Trustees, Sioux City, Ia...	1903
BARTOW, EDWARD.	
Director State Water Survey, University Illinois, Urbana, Ill.....	1906
BASSETT, CARROL P., C. E.	
Treas. Commonwealth Water & Light Co., Summit, N. J.	1906
BASSETT, GEO. B.	
Civil Engr., 290 Terrace, Buffalo, N. Y.....	1898
BAUMAN, C. V.	
Water Comr., Newark, N. J.....	1900
BEARDSLEY, JOSEPH C.	
1200 Scofield Bldg., Cleveland, Ohio.....	1903
BECKER, GEORGE.	
City Engineer's Office, Seattle, Wash.....	1905
BELCHER, DONALD M.	
Sanitary Engr. Board of Public Service, 506 American Savings Bank Bldg., Columbus, Ohio.....	1906
BEMIS, EDWARD W.	
Supt. Water-Works, 178 Kensington St., Cleveland, O...	1903

Date of Admission.

BENNETT, THOS. H.
Oswego, N. Y. 1898

BENZENBERG, G. H.
Cons. Engr., 312 Wells Bldg., Milwaukee, Wis. 1888

BERRY, J. P.
Supt. Water-Works, Waterloo, Iowa 1896

BETTS, CHARLES R.
Chief Engr. Queens Co. Water-Works, Far Rockaway, L. I., N. Y. 1901

BINDER, FREDERICK C.
Asst. Supt. & Treas. Water Co., Jefferson City, Mo. 1904

BISHOP, JOHN L.
Sec. & Supt. Water-Works, Salina, Kan. 1893

BISSETT, EDWIN H.
Metals Broker, 717 Union Bank, Winnipeg, Man. 1898

BLAKE, C. H. M.
Con., Hyd. & Sanitary Engr., Apartado postal 94, Guadalajara, Mex. 1906

BLAKE, EDMUND M., C. E.
8 Beacon St., Boston, Mass. 1906

BLOSSOM, FRANCIS.
Engineer & Contractor, 52 William St., New York, N. Y. 1906

BOARDMAN, ARTHUR EDWIN.
Pres. Tampa, Fla., Water-Works Co., Room 1707, 41 Wall St., New York, N. Y. 1903

BOARDMAN, W. H.
Civil Engr., 2203 E. Dauphin St., Philadelphia, Pa. 1893

BOEH, W. H.
Chief Engr., Water-Works, Cincinnati, Ohio 1900

BOGART, JOHN.
Civil Engr., 16 Exchange Place, New York, N. Y. 1892

BOLGER, F. E.
Secretary Water-Works, City Bldg., Springfield, Ohio 1903

BOLLING, CHAS. E.
Superintendent Water-Works, Richmond, Va. 1891

BOLTON, CHANNING M.
Chief Engr. Water-Works, Charlottesville, Va. 1906

BOND, JOSEPH A.
Civil Engr., Wilmington, Del. 1888

BOOKER, GEO. E.
Chief C. S. V. W. W. Co., 126 Stockton St., San Francisco, Cal. 1891

BOWKER, CHAS. L.
Supt. Brunswick & Topsham Water District, Brunswick, Maine 1906

BRACKENRIDGE, GEORGE W.
San Antonio, Texas 1888

	Date of Admission.
BRACKETT, DEXTER.	
Engr. Sudbury & Metropolitan Water-Works Distribution Depts., 1 Ashburton Place, Boston, Mass.....	1906
BRIGHTMAN, HORACE I.	
Sec. Staten Island Water Supply Co., 50 Broadway, New York, N. Y.....	1902
BROOKS, ISAAC W.	
Pres. Water Co., Torrington, Conn.....	1889
BROTHERTON, CHAS. F.	
Mgr. Water Co., Ashtabula, Ohio.....	1904
BROUGH, WALTER CONSTANTINE.	
C. E., Goderich, Can.....	1897
BROWN, CHARLES CARROLL.	
Consulting Engineer and Editor Municipal Engineer, Commercial Club Bldg., Indianapolis, Ind.....	1905
BROWN, C. ARTHUR.	
Sanitary Engineer, 917 The Rookery, Chicago, Ill.....	1905
BROWN, CALVIN S.	
54 Canal St., Chicago, Ill.....	1882
BUNKER, GEORGE CYRUS.	
Chemist & Biologist, Littleton, N. H.....	1906
BURLEIGH, JOHN J.	
Sec. & Treas. Merchantville Water Co., 5th & Market Sts., Camden, N. J.....	1895
BURNETT, M.	
Supt. Water Works, Paducah, Ky.....	1889
BURNS, T. W.	
City Engineer & Supt. Water-Works, Fairbury, Ill.....	1905
BURTON, HENRY.	
Supt. & Chief Engr. Water-Works, Port Huron, Mich...	1906
BUSH, JOHN C.	
Supt. of Meters, 541 Chenango St., Binghamton, N. Y...	1906
CAHILL, STEPHEN A.	
Supt. Water-Works, Manistee, Mich.....	1890
CAIN, W. L.	
Supt. of Water Co., Tyler, Tex.....	1903
CAIRD, JAMES M.	
Chemist & Bacteriologist, 271 River St., Troy, N. Y....	1900
CALDWELL, JAMES H.	
C. E., 55 First St., Troy, N. Y.....	1906
CALHOUN, H. L.	
Sec. Water Works, Fort Worth, Texas.....	1903
CALPINS, WILLIS N.	
318 Dearborn St., Chicago, Ill.....	1901
CAMPBELL, CHARLES H.	
431 Equitable Bldg., Atlanta, Ga.....	1895

Date of Admission.

*CAMPBELL, J. A.
Supt. & Sec. Ocala Water Co., Ocala, Fla..... 1906
CAMPBELL, JAMES J.
Supt. Water Works, Menominee, Mich..... 1902
CAPPELEN, F. W.
Cons. Engr., 610 Globe Bldg., Minneapolis, Minn..... 1893
CARLIN, PHIL.
Supt. Water-Works, Sioux City, Iowa..... 1891
CARLSON, J. A.
Water Comr., Stromburg, Neb..... 1904
CARROLL, EUGENE.
Chief Engr. and Supt. Water, Butte, Mont..... 1904
CARTER, C. D.
Supt. Water & Sewage, Charlottesville, Va..... 1906
CASE, E. W.
Colorado Springs, Colo..... 1902
CASE, L. N.
Mgr. & Sec. Water & Light Dept., Duluth, Minn..... 1889
CAULFIELD, JOHN.
Sec. Water-Works, St. Paul, Minn..... 1887
CHAPIN, L. E.
Cons. Engr., Water-Works, Canton, Ohio..... 1899
CHATHAM, J.
Supt. Water-Works, Iowa City, Ia..... 1892
CHIPMAN, WILLIS.
Civil Engr., 103 Bay St., Toronto, Can..... 1888
CHISHAM, J. M.
Supt. Water Co., Atchison, Kan..... 1902
CHISOLM, EDWARD NORTH.
City Engr. & Supt. Water-Works, Columbia, S. C..... 1906
CLARK, ALBERT.
Supt. Water-Works, Bellingham, Wash..... 1906
CLARK, D. H.
Supt. City Water Works, Ironton, Ohio..... 1904
CLARK, H. W.
Treas. & Gen. Mgr. Clear Water Co., Mattoon, Ill..... 1895
CLARK, J. V.
Supt. Citizens' Water Co., Washington, Pa..... 1903
CLARK, RICHARD.
Supt. Water Works, Merritton, Ont..... 1905
CLAYTON, R. M.
City Engr., Atlanta, Ga..... 1891
COBB, CHARLES H.
Supt. Water-Works, Kankakee, Ill..... 1904
COLE, EDWARD S.
Hydraulic Engr., Room 21-I, 220 Broadway, New York, N. Y..... 1902

	Date of Admission.
COLE, JOHN A.	
Hydraulic Engr., Old Colony Bldg., Chicago, Ill.	1889
*COLE, W. W.	
Gen'l Mgr., Elmira Water, Light & Railroad Co., Elmira, N. Y.	1906
CONARD, W. R.	
Inspector of Materials, Savings Institution Bldg., Burlington, N. J.	1904
CONLIN, F.	
Water Comr., 355 Market St., Bethlehem, Pa.	1904
CONLON, THOMAS.	
Supt. Water Dept., Tucson, Arizona.	1906
CONNOR, F. J.	
Supt. Water-Works, Faribault, Minn.	1900
COOK, F. S.	
Asst. Engr. Croton Aqueduct Commission, 26 Landscape Ave., Yonkers, N. Y.	1904
COOK, JOHN H.	
Hyd. Engr. East Jersey Water Co., 158 Ellison St., Paterson, N. J.	1906
COOK, T. R.	
Toledo, Ohio.	1897
CORR, ANDREW S.	
Inspector of Cast Iron Pipe, 146 Washington St., Phillipsburg, N. J.	1905
CRANDALL, WM. S.	
Engr. & Journalist, 253 Broadway, New York, N. Y.	1901
CROLL, EMIL A.	
Supt. Water Works, Iron Mountain, Mich.	1893
CROWTHER, HENRY, M. E.	
400 Chestnut St., Philadelphia, Pa.	1906
CUDDEBACK, ALLEN W.	
Engr. & Supt. Passaic Water Co., 158 Ellison St., Paterson, N. J.	1904
CULLINANE, J. R.	
Mgr. West St. Louis Water & Light Co., St. Louis, Mo.	1906
DAVIS, F. A. W.	
Vice-pres. and Treas. Water Co., Indianapolis, Ind.	1886
*DAVIS, L. H.	
Chief Engr. Tagona Water & Lt. Co., Sault Ste. Marie, Ont.	1906
DAVY, T. W.	
Supt. Water Works, Middletown, N. Y.	1901
DEARBORN, H. M.	
Supt. City Water-Works, Fernandina, Fla.	1906
DEERY, JOHN JEROME.	
Archt. and Engr., Betz Bldg., Philadelphia, Pa.	1901

Date of Admission.

DEFFENBAUGH, J. M.
Water Comr., Lincoln, Neb..... 1904

DEIGNAN, JOHN E.
Asst. Engr. Dept. Water Supply N. Y. City, 11 Winthrop Terrace, East Orange, N. J..... 1906

DE SAUSSURE, WILLIAM P.
Vice-Pres. Vinton-Roanoke Water Co., 1103 Main St., Richmond, Va..... 1900

DEVINE, P. H.
Supt. of Public Works, Ishpeming, Mich..... 1903

DE YOUNG, JAMES.
Supt. Public Works, Holland, Mich..... 1905

DILL, H. A.
Supt. Water Works, Richmond, Ind..... 1900

DIVEN, J. M.
Supt. Water Works, Charleston, S. C..... 1884

DONAHUE, J. P.
Secretary and Treasurer Water Co., Davenport, Iowa.. 1884

DOW, A. R.
Supt. Water-Works, Salem, Ohio..... 1902

DOWNES, JOHN R.
Chemist and Bacteriologist Water Dept., Box L, Filter Plant, Harrisburg, Pa..... 1906

DRISCOLL, MARTIN A.
Pres. Haverstraw Water Supply Co., Haverstraw, N. Y.. 1906

DRUMMOND, M. J.
Pres. Green Island Water Supply Co., Green Island, N. Y. 1901

DUNBAR, E. L.
Secretary and Supt. Water Works, Bay City, Mich..... 1886

DUNBAUGH, GEORGE J.
President Water Company, Pueblo, Colo..... 1897

DUNHAM, H. F.
Consulting Engineer, 220 Broadway, New York, N. Y... 1884

DURLIN, WILLIS B.
Water Commissioner, Erie, Pa..... 1903

EATON, HARVEY D.
Council for Water District Trustees, Waterville, Me.... 1903

EGGERS, AUGUST F.
Water Commissioner, Newark, N. J..... 1904

ELBERT, EDWARD.
Water Commissioner, Reading, Pa..... 1904

ELEY, FRANK.
Water Purveyor, 460 Ave. E, Bayonne, N. J..... 1906

ELLIS, ROBERT N.
Civil Engineer, Jacksonville, Fla..... 1890

Date of Admission.

ELLISON, B. F.
Gen. Mgr. Superior Water, Light & Power Co., West Superior, Wis. 1893

ELLSWORTH, EMORY A.
Civil and Hydraulic Engineer, Holyoke, Mass. 1904

ELLWANGER, JOHN.
Pres. Water-Works Trustees, 1392 Main St., Dubuque, Iowa 1903

EMERY, EZRA L.
Supt. Green River Water-Works Co., Rock Springs, Wyo. 1897

ERICSON, JOHN E.
1914 Arlington Place, Chicago, Ill. 1897

EVANS, JAMES RITTENHOUSE.
Chemist and Bacteriologist, 232 High St., Pottstown, Pa. 1905

FAIRFIELD, E. M.
General Manager Water Co., Omaha, Neb. 1902

FANNING, J. T.
Consulting and Civil Engineer, 330 Hennipen Ave., Minneapolis, Minn. 1886

FARLEY, JOHN M.
Consulting Engineer, White Plains, N. Y. 1902

FELIX, GEORGE H.
President Reading Suburban Water Co., Reading Pa. 1893

FELLOWS, C. L.
Deputy City Engineer, Toronto, Can. 1904

FENN, CHAS. W., C. E.
Mgr. Water Works, 11 Exchange St., Portland, Me. 1905

FERGUSON, W. H.
Supt. Water Works, Springfield, Ohio 1905

FEWELL, J. H.
Supt. Light, Heat and Water Co., Jackson, Miss. 1906

FISHER, E. A.
City Engineer, Rochester, N. Y. 1901

FITCH, W. P.
Supt. Water Dept., Mason City, Iowa 1904

FITZPATRICK, JAMES R., C. E.
Genl. Mgr. Grand Rapids Hydraulic Co., Grand Rapids, Mich. 1905

FOLWELL, A. PRESCOTT, Editor "Municipal Journal and Engineer," Flatiron Building, New York, N. Y. 1906

FORBES, MURRAY.
Supt. and Secretary Irwin Water Co., Greensburg, Pa. 1891

FORD, EDWIN H.
Supt. Water Works, Hartford City, Ind. 1901

Date of Admission.

Foss, W. E.
Divn. Engr. Metropolitan Water-Works, Boston, Mass.. 1906

Foster, Ernest H.
Mechanical Engineer, 111 Broadway, New York, N. Y... 1901

Fox, Chas. J.
Supt. Water Co., Cedar Rapids, Ia..... 1902

Frailey, E. F.
Supt. Water-Works, Lancaster, Pa..... 1896

French, Arthur N.
Supt. Hyde Park Water Co., Hyde Park, Mass..... 1906

French, D. W.
Supt. Hackensack Water Co., P. O. Box 98, Weehawken, N. J..... 1895

French, E. V.
M. E., 31 Milk St., Boston, Mass..... 1906

Fuertes, James H.
Con. Engr. for Hydraulic and Sanitary Works, 140 Nassau St., New York, N. Y..... 1906

Fuller, Allen J.
Gen. Supt. Bureau of Water, City Hall, Philadelphia, Pa. 1901

Fuller, Frank L., C. E.
12 Pearl St., Boston, Mass..... 1906

Fuller, George W.
Consulting Expert Water Purification, 170 Broadway, New York, N. Y..... 1898

Gailey, S. A.
Supt. Water Dept., Altoona, Pa..... 1899

Gallagher, John F.
Supt. Water Works, Kingston, N. Y..... 1904

Gannon, Thomas W.
Supt. Water Works, Cairo, Ill..... 1904

Gardner, L H.
1013 Hibernia Bank Bldg., New Orleans, La..... 1883

Garrison, Ralph H.
Supt. Public Works, 817 Wood St., Vineland, N. J..... 1904

Gates, H. V.
Pres. Prineville Water & Light Co., Hillsboro, Ore..... 1904

Gedney, Jerome D.
Chairman Water Committee, East Orange, N. J..... 1903

Gerrish, William Blanchard.
Supt. Water Works, Oberlin, Ohio..... 1905

Getchell, Williams Basset.
City Engineer, Augusta, Me..... 1904

Giclas, Eli.
Supt. Water-Works, Flagstaff, Arizona..... 1905

Giesler, Arthur.
Consulting Engineer, 29 Broadway, New York, N. Y.... 1906

	Date of Admission.
GLAZIER, W. L.	
Supt. Water-Works, Newport, Ky	1902
GLORE, W. H.	
Covington, Ky	1890
GLOVER, ALBERT S.	
Secretary Hersey Mfg. Co., 714 Tremont Temple, Boston, Mass	1885
GOODELL, J. M.	
Hydraulic Engineer, Editor Engineering Record, 114 Liberty St., New York, N. Y	1894
GOODNOW, W. T.	
Gen. Mgr. Water Co., Sayre, Pa	1889
GOODWIN, WM. G.	
Engineer Water-Works, Trinidad, Col	1902
GOULD, URIAH.	
Chief Engineer Pumping Station, Detroit, Mich	1903
GRAY, H. B.	
Registrar Water-Works, Minneapolis, Minn	1906
GREGORY, JOHN HERBERT.	
Engr. in Charge Impvd. Water and Sewage Works, 506 American Savings Bank Bldg., Columbus, O	1906
GRIFFIN, J. WILLIAM.	
Supt. New Jersey Suburban Water Co., Arlington, N. J	1904
GUBELMAN, FRED. J.	
Vice-Pres. O'Rourke Engineering Construction Co., 1 West 34th St., New York, N. Y	1897
GUILFORD, ANDREW J.	
Mechanical Engineer, The Rookery, Chicago, Ill	1889
GWINN, DOW R.	
President Water Co., Terre Haute, Ind	1893
HAGUE, C. A.	
Consulting Engineer, 52 Broadway, New York, N. Y	1886
HALE, A. K.	
Treasurer and Manager Water Co., Ann Arbor, Mich	1903
HALL, J. W.	
HAMILTON, W. S.	
Supt. Water-Works, Youngstown, Ohio	1883
Manager Water Co., Stockton, Cal	1904
HAND, F. L.	
1948 N. 18th St., Philadelphia, Pa	1901
HARBSTER, M.	
Water Commissioner, Reading, Pa	1901
HARDY, A. W.	
Inspector and Hydraulic Engineer, 240 La Salle St., Chicago, Ill	1904
HARLOW, GEORGE R.	
Constructing Engineer, 204 Hawthorn St., Edgewood, Swissvale, P. O., Pa	1884

Date of Admission.

HARLOW, JAMES H.
Chief Engineer, Susquehanna Power Co., Conowingo, Md. 1891

HARRISON, EDLOW WINGATE.
Civil Engr., 15 Exchange Place, Jersey City, N. J..... 1906

HART, ED. W.
General Manager Water Co., Council Bluffs, Ia..... 1896

HARVEY, LEE.
Supt. Water Co., Conneaut, Ohio..... 1905

HATCH, EDWARD L.
Asst. Treas. Stamford Water Co., Stamford, Conn..... 1906

HATTON, T. CHALKLEY.
Consulting Engineer, 608 Market St., Wilmington, Del.. 1902

HAWKS, W. E.
President and Treasurer Water-Works, Bennington, Vt.. 1892

HAYDEN, N. W.
Pres. Windsor Water Co., Windsor, Conn..... 1906

HAZELHURST, J. N.
Consulting Engineer, Mobile, Ala..... 1906

HAZEN, ALLEN.
Civil Engineer, 220 Broadway, New York, N. Y..... 1896

HEALEY, G. B.
President of Board of Trustees, 316 Toy Bldg., Sioux City, Iowa..... 1903

HEEGER, EMIL I.
Member Water Works Board, Evansville, Ind..... 1902

HEERMANS, H. C.
Supt. Water-Works Co., Corning, N. Y..... 1886

HEIM, J. B.
Supt. Water-Works, Madison, Wis..... 1893

HEISLER, CHAS. L.
Mechanical Engineer, St. Mary's, Ohio..... 1904

HENDERSON, CHARLES R.
117½ Bridge St., Waterloo, Iowa..... 1901

HERING, RUDOLPH.
Hydraulic and Sanitary Engineer, 170 Broadway, New York, N. Y..... 1887

HERMANY, CHARLES.
Chief Engineer and Supt. Water-Works, Louisville, Ky.. 1889

HERSCHEL, CLEMENS.
Hydraulic Engineer, 2 Wall St., New York, N. Y..... 1892

HEWITT, THOMAS.
Supt. Water-Works, Kingston, Ontario..... 1906

HIBBELER, H. D.
Secretary and Treasurer Water Co., Washington, Mo... 1904

	Date of Admission.
HIGBEE, I. M.	
Supt. Water-Works, Lewisburg, Pa.	1904
HIGH, S. Y., M. E.	
Supt. Water-Works, 6515 Indp. Ave., Kansas City, Mo.	1906
HILL, JOHN W.	
Consulting Engineer, 1st National Bank Bldg., Cincinnati, Ohio	1886
HILL, WILLIAM R.	
Consulting Engr., 242 Sixth Ave., Brooklyn, N. Y.	1897
HILLABRANDT, LUCIAN.	
Supt. Water-Works, Johnstown, N. Y.	1906
HINES, FRANK L.	
Supt. Water Dept., Salt Lake City, Utah	1906
HOAGLAND, IRA GOULD.	
Mechanical Engineer, Room 533, Equitable Bldg., Atlanta, Ga.	1904
HOBBS, A. L.	
Supt. and Secretary Water-Works, Raton, N. Mex.	1902
HODGKINS, H. C.	
Civil Engineer, 508 Kirk Bldg., Syracuse, N. Y.	1888
HODGSON, JOHN S.	
Wellington, Mass.	1906
HOLLINGSWORTH, ROBERT.	
Chief Engineer, Water Dept., Camden, N. J.	1905
HOLMES, A. G.	
P. O. Box 252, East Pittsburg, Pa.	1906
HOLMES, ALBA L.	
Hydraulic Engineer, 574 Wealthy Ave., Grand Rapids, Mich.	1900
HOOPER, THOMAS N.	
Vice-President Water Co., Davenport, Ia.	1884
HOPKINS, JAMES A.	
Supt. Water Works, Colorado Springs, Colo.	1897
HORNER, CHARLES M.	
Asst. Supt., Water-Works Co., 803 Ohio Ave., East St. Louis, Ill.	1903
HORNUNG, GEORGE.	
Consulting Civil and Mechanical Engineer, 612 Johnson Bldg., Cincinnati, Ohio	1887
HORTON, HORACE E.	
Civil Engineer, Chicago Bridge & Iron Co., Chicago, Ill.	1904
HOUSTON, GEORGE.	
Water Commissioner, Kalamazoo, Mich.	1904
HUBBELL, CHARLES W.	
Civil Engineer, Water Board, Detroit, Mich.	1903

Date of Admission.

HUGGINS, D. E.
Manager Water Works, Streator, Ill..... 1896

HULLEY, ELKANAH.
Superintendent Water-Works, Marion, Ind..... 1898

HUMPHREYS, WILLIAM HENRY.
Engineer, Manager and Secretary Water-Works Co., Lendal Bridge, York, England..... 1904

HUNTER, T. B.
Resident Engr. M. C. W. W., Monterey, Cal..... 1906

HUNTER, W. J.
Manager Charters Valley Water Co., 235 Orchard St., Knoxville, Pittsburg, Pa..... 1903

*HUTH, FRANK.
Sec. and Treas., Nazareth, Penna..... 1906

HUTTON, GEORGE J.
Water Commissioner, Harrisburg, Pa..... 1904

HUTZEL, TITUS F.
Superintendent Water Co., Ann Arbor, Mich..... 1903

JACKSON, ROBERT A.
Supt. Insurance and Water Co., Norristown, Pa..... 1903

JEFFERIS, LOUIS M.
Constructing Engineer, 623 Vennica Ave., East St. Louis, Ill. 1904

JEWELL, WM. M.
Chemical and Consulting Engr., Cable Bldg., Chicago, Ill. 1906

JONES, A. J.
P. O. Box 273, New Brunswick, N. J..... 1884

JONES, BURK.
Supt. Water-Works, Hattiesburg, Miss..... 1906

KASTBERG, KARL C.
City Engr., and Supt. Water-Works, Boone, Iowa..... 1904

KEELER, H. E.
Room 633, "The Rookery," Chicago, Ill..... 1887

KELLEY, JOHN C.
Director Water-Works, 84-86 Chambers St., New York, N. Y..... 1890

KELLEY, NICHOLAS J.
Supt. Depew and Lake Erie Water Co., 1361 Abbott Road, Buffalo, N. Y..... 1903

KELLOGG, R. M.
Supt. Middlesex Water Co., Metuchen, N. J..... 1901

KENNEDY, GEORGE C.
Supt. Water Works, Harrisburg, Pa..... 1904

KIMBALL, FRANK C.
14 Beacon St., Boston, Mass..... 1902

	Date of Admission.
KING, ADOLPHE, J.	
Gen. Mgr. Water Works, Alamorgodo, New Mexico....	1904
KINGSLEY, MARVIN W.	
Civil Engr., Rose Bldg., Cleveland, Ohio.....	1899
KINNICUTT, LEONARD P.	
Director Dept. of Chemistry, Worcester Polytechnic Inst., Worcester, Mass.....	1906
KLINGBERG, W.	
Civil Engr., Kingston, N. Y.....	1906
KNOX, H. E., JR.	
Hydraulic Engineer, Piedmont Bldg., Charlotte, N. C...	1901
KNOX, W. F.	
Secretary Water Co., Tyler, Texas.....	1896
KNUDSON, A. A.	
Electrical Engineer, 34 Nassau St., New York, N. Y....	1900
KOENIG, ARNOLD C.	
Sec. Board Water Commissioners, 514 Bee Bldg., Omaha, Neb.....	1901
KUHN, W. S.	
Gen. Mgr. American Water-Works and Guarantee Co., P. O. Box 1103, Pittsburg, Pa.....	1886
KUICHLING, E.	
Civil Engr., 52 Broadway, New York, N. Y.....	1896
LANDES, J. D.	
Sec. and Treas. Canajoharie, N. Y., Water Supply Co., Mechanicsburg, Pa.....	1904
LATTA, L. M.	
Gen. Mgr. Akron Water Works Co., Akron, Ohio.....	1906
LAUTZ, HENRY.	
Supt. Pekin Water-Works Co., Pekin, Ill.....	1896
LAWTON, RALPH W.	
Mechanical Engineer, 10 Clive St., Calcutta, India.....	1906
LECONTE, L. J.	
Civil and Con. Engr., P. O. Box 482, Oakland, Cal.....	1886
LEFAVOR, WALTER L.	
Manager Water Co., Springfield, Mo.....	1904
LEISEN, THEODORE ALFRED.	
Chief Engr. Water Dept., Wilmington, Del.....	1904
LEVERING, W. A.	
Supt. W. P. Extension, 317 City Hall, Chicago, Ill.....	1906
LEVY, ERNEST C., M. D.,	
Bacteriologist & Director of Laboratory of City Water Dept., Richmond, Va.....	1905
LITTERER, FRED	
Chief Engr. Water-Works, 920 N. Union St., Decatur, Ill.	1906
LITTLE, BEEKMAN C.	
Supt. Water-Works, 44 City Hall, Rochester, N. Y.....	1903

Date of Admission.

LOCHRIDGE, ELBERT E.,
Engineer Water Dept., 43 Bridge St., Springfield, Mass.. 1906

LOCKE, J. W.
Asst. Supt. Water-Works, Brockton, Mass..... 1896

LOCKWOOD, CHARLES A.
Pres. Jamaica Water Supply Co., Jamaica, L. I., N. Y... 1903

LOETZER, C. E.
Supt. Sayre Water Co., Sayre, Pa..... 1906

LONGYEAR, O. C.
23 S. Portland Ave., Brooklyn, N. Y..... 1898

LOOMIS, E. L.
Supt. Valparaiso Home Water Co., Valparaiso, Ind.... 1906

LORD, HARRY A.
Supt. Water-Works, Ogdensburg, N. Y..... 1903

LORENZ, JOHN
Electric Light & Power Co., Jackson, Miss..... 1902

LOVELL, WALTER D.
1415 Eighth St., S. E., Minneapolis, Minn..... 1898

LUCAS, FRED L.
Mgr. & Secy. Light & Water Co., Pontiac, Ill..... 1903

LUDLOW, J. L.
Con. Engr., Winston-Salem, N. C..... 1904

LYON, HENRY L.
Deputy Water Commissioner, Buffalo, N. Y..... 1903

MCALPINE, A. H.
Genl. Western Agent Hersey Mfg. Co., 426 N. High St., Columbus, Ohio..... 1889

MCARTHUR, ARTHUR
Supt. Water Works, Dubuque, Iowa..... 1902

*MCCABE, H. DALLAS
Supt. Water Co., Monessen, Pa..... 1905

MCCARTHY, DANL. B.
Supt. Water-Works, Waterford, N. Y..... 1905

MCCONNELL, J. H.
Supervisor Water Dept., Minneapolis, Minn..... 1901

MCCONNELL, W. C.
Pres. Water Company, Shamokin, Pa..... 1888

MCCORKINDALE, WM. J.
Genl. Mgr. Marquette Co. Gas & Electric Co., Ispheming, Mich..... 1903

MCCORMICK, W. T.
Water Works Contractor, Charlotte, N. C..... 1896

MCCUE, W. F.
Care Colo. Fuel & Iron Co., Boston Bldg., Denver, Colo. 1897

	Date of Admission.
McDargh, Harry J.	
Civil & Hyd. Engr. Maintenance, Dept. of Water, Dayton, Ohio	1906
MacDermot, L. C.	
Supt. Water Dept., 26 South Walnut St., East Orange, N. J.	1903
MacDonald, Emmett	
Supt. Water & Light Co., Lincoln, Ill	1904
MacGonigle, Dr. John N.	
Supt. Water Works, Miami & Palm Beach, Miami, Fla	1906
McGrath, Robert H.	
Water-Works Trustee, Lafayette, Ind	1904
McGilvray, Thomas T.	
City Engr., Duluth, Minn	1903
McKim, Robert Aldert.	
Asst. Engr. New Croton Aqueduct, 34 W. 91st St., New York, N. Y	1902
McLeod, T. T.	
Mgr. Water Co., Missoula, Mont	1904
McNamee, T. W.	
Supt. Water Co., Wabash, Ind	1903
McWilliams, C. Q.	
Pres. Roaring Creek Water Co., P. O. Box 85, Shamokin, Pennsylvania	1901
Maignen, P. A.	
Water Engineer, 52 N. 13th St., Philadelphia, Pa	1900
Manley, Samuel C.	
Pres. & Gen. Mgr. Maine Water Co., Augusta, Me	1903
Manville, F. D.	
Local Mgr. Newport News Light & Water Co., Newport News, Va	1901
Marple, Wm. M.	
Chief Engr. Gas and Water Co., Scranton, Pa	1905
Martin, H. P.	
Supt. Water Works, Owensboro, Ky	1888
Mason, W. P., Dr.	
Prof. Chemistry, Rennsselaer Poly. Institute, Troy, N. Y.	1892
Mather, Edmund	
Pres. Water Board, Harrisburg, Pa	1891
Maury, Dabney H.	
Con. Engr., 129 North Jefferson Ave., Peoria, Ill	1894
Mead, Daniel W.	
Con. Engr., First National Bank Bldg., Chicago, Ill	1889
Mellon, T. A.	
Pres. Kensington Water Co., 514 Smithfield St., Pittsburg, Pa	1903

Date of Admission.

MERCER, E. A.
Supt. Water-Works, West Chester, Pa..... 1906

MERRILL, ANDREW S.
Supt. Bath Division Maine Water Co., Bath, Maine.... 1906

MERRITT, D. S.
Engr. & Supt. Board of Water Commissioners, Tarrytown, N. Y..... 1906

METCALF, LEONARD
Con. Civil Engr., 14 Beacon St., Boston, Mass..... 1903

MEYERS, A. H.
Supt. Water Co., Columbia, Pa..... 1903

MICHIE, JOHN C., C. E.
Supt. Water Co., Durham, N. C..... 1903

MILLER, J. A.
Supt. Water Co., Louisiana, Mo..... 1904

MILLER, JOSEPH TORRENCE
Secy. and Treas. Pennsylvania Water Co., 424 Maple Ave., Edgewood, Pittsburg, Pa..... 1903

MILLIGAN, R. E.
Chemist, 15 Broad St., New York, N. Y..... 1902

MILNE, ALEXANDER
Supt. Water-Works, St. Catharines, Ontario, Can.... 1903

MILNER, W. J.
Care Tutwiller Coal & Coke Co., New Orleans, La..... 1884

MILTON, RICHARD H.
Supt. Water-Works, Reidsville, N. C..... 1902

MIXER, CHAS. A.
Engr., Light & Water Co., Rumford Falls, Me..... 1906

MOLIS, WM.
Supt. Water-Works, Muscatine, Iowa..... 1882

MONFORT, WILSON F.
Chemist Water Dept., 77 May St., St. Louis, Mo..... 1906

MONJEAU, C.
Hydraulic Engineer, Middletown, Ohio..... 1889

MONROE, H. G.
Supt. Water-Works, Pontiac, Mich..... 1906

MOORE, JOHN M., C. E.,
Engr. & Supt., London, Ont..... 1906

MOTH, R. H.
Civil Engr. & Supt. Water-Works, Kenosha, Wis..... 1901

MULHALL, JOHN F. J.
Public Accountant, 62 Astoria St., Boston, Mass..... 1905

MURPHY, HOWARD
Civil, Hyd. & Sanitary Engr., 260 S. Third St., Philadelphia, Pa..... 1906

	Date of Admission
MYERS, GEO. M.	
Pres. Water & Light Co., 505 New England Bldg., Kansas City, Mo	1902
NETTLETON, CHARLES H.	
Agent Birmingham Water Co., Derby, Conn	1888
NEVILLE, THOMAS J.	
Comr. Public Works, Rochester, N. Y	1888
NEWTON, HOWARD D.	
Pres. Water-Works Co., 175 Broad St., Norwich, N. Y	1903
NOURSE, H. O.	
Supt. Bureau of Water, Chicago, Ill	1903
NUEBLING, EMIL L.	
Supt. and Engr. Water Dept., Reading, Pa	1895
OHLIGER, L. B.	
Supt. Water-Works, Canton, Ohio	1899
OMBERG, JAMES A.	
City Engr., Memphis, Tenn	1905
O'SHAUGHNESSY, JERRY	
Supt. Department of Water, Columbus, O	1897
PARKIN, R. R.	
Supt. Water-Works, Elgin, Ill	1890
PATERSON, ARTHUR C.	
Supt. Water-Works, Everett, Wash	1901
PATTON, W. A.	
Pres. and mgr. Catlettsburg, Kenora & Ceredo Water Co., Catlettsburg, Ky	1904
PAYSON, EDGAR R.	
Treas. and Supt. Water Co., 33 Plum St., Portland, Me	1905
PEASE, WALTER D.	
City Engr. and Water Comr., P. O. Box 218, Cheyenne, Wyoming	1905
*PECK, JOHN W.	
Supt. Water-Works, Evansville, Ind	1906
PEENE, EDWARD L.	
Supt. Water-Works, Yonkers, N. Y	1901
PENNEY, C. L.	
Edgewood Park, Pa	1902
PERRY, WILLIAM	
Hydraulic Engr., Maplewood Ave., Cote des Neiges, Montreal, Quebec	1886
PHILLIPS, GEO. H.	
Street and Water Comr., Newark, N. J	1906

Date of Admission.

PHILLIPS, T. C.
Water-Works Engr., 5426 Indiana Ave. Chicago, Ill.... 1905

PITCHER, F. H.
Gen. Mgr. and Chief Engr. Montreal Water & Power Co., 62 Alliance Bldg., Montreal, Can..... 1905

PITT, B. R.
Pres. Water-Works Co., Pensacola, Fla..... 1896

POETSCH, CHARLES J.
City Engr. and Pres. Board of Public Works, Milwaukee, Wisconsin 1903

POLLARD, W. D.
Engr. Water-Works, Pottsville, Pa..... 1892

POTTS, CLYDE
Civil and Sanitary Engr., 17 Battery Place, New York, N. Y..... 1906

POWELL, SHEPHERD T.
Water Analyst, 31 Burdette Ave., Troy, N. Y..... 1906

PRENTER, MARTIN
Sec. and Gen. Mgr. Monongahela Water Co., 1113 Carson St., Pittsburg, Pa..... 1903

PRENTICE, ALLEN T.
Mechanical Engr., 499 N. State St., Chicago, Ill..... 1890

PRIDDY, CHAS. N.
Sec. and Supt. Water-Works, Leadville, Colo..... 1886

PRINCE, EDWARD
Consulting Engineer, Quincy, Ill..... 1906

PRINCE, GEORGE T.
The Denver Union Water Co., Denver, Colo..... 1906

PUGH, MARSHALL R.
Civil Engr., 1334-5 Real Estate Trust Bldg., Philadelphia, Pa..... 1905

PURDY, J. H.
Supt. American Water-Works & Guarantee Co., P. O. Box 1103, Pittsburg, Pa..... 1896

QUICK, ALFRED MERRITT ..
Water Engineer, Baltimore, Md..... 1901

RANDOLPH, W. C. N., JR.
Supt. Water-Works, Lynchburg, Va..... 1902

RAPP, W. M.
Supt. Construction Water Dept., Atlanta, Ga..... 1899

REAGAN, JOHN F., JR.
General Mgr. Consolidated Water Co., Utica, N. Y.... 1906

REED, WILBUR F.
Supt. Water-Works, Kalamazoo, Mich..... 1901

*REIMER, ARTHUR A.
Supt. Water Dept., City Hall, East Orange, N. J..... 1906

	Date of Admission.
REYER, GEORGE	
Supt. N. Y. Inter-Urban Water Co., Mt. Vernon, N. Y.	1884
RILEY, LEE	
Chief Engr. Metropolitan Water Co., Kansas City, Kan..	1897
ROBERTSON, GEO. H.	
Supt. Water-Works, Yarmouth, N. S.....	1888
ROBERTSON, WM. F.	
Supt. Clarendon Water Co., Wilmington, N. C.....	1903
ROBINSON, WM. P.	
Mgr. The Denver Union Water Co., Denver, Colo.....	1897
ROBINSON, SIDNEY C.	
Mgr. Water-Works, Walkersville, Ontario, Can.....	1904
ROBLIN, FRED B.	
Mgr. Water & Electric Co., Kalispell, Mont.....	1905
ROHRBACH, WM. R.	
Mgr. Sunbury Water Co., Sunbury, Pa.....	1906
ROLFE, W. E.	
Engr. of Distribution Water Dept., 3855 Flad Ave., St. Louis, Mo.....	1904
ROSAMOND, S. J.	
Supt. Municipal Water-Works Co., Fort Smith, Ark..	1898
ROSS, CHAS. H.	
Supt. Water Company, Waterloo, N. Y.....	1906
ROWE, CHARLES E.	
Gen'l Mgr. Water Company, Goldfield, Nev.....	1901
RUSSELL, W. S.	
Dickinson, N. D.....	1895
RUST, C. H.	
City Engr. and Mgr. Water-Works, Toronto, Ont., Can.	1903
RUTHRAUFF, HARRY	
Water and Plumbing Inspector, Decatur, Ill.....	1898
RUTLEDGE, GEO. H.	
Supt. Water and Light Co., Concord, N. C.....	1906
RYDER, PHILIP F.	
Vice-Pres. and Treas. Water-Works Trustees, Dubuque, Iowa.	1903
SALMON, C. B.	
Owner Water-Works, Beloit, Wis.....	1902
SALMON, FREDERICK WILLIAM	
Civil and Mechanical Engr., 127 S. Central Ave., Burlington, Iowa	1906
SANDO, WILL J.	
Water-Works Commercial Consulting Engr., care of Allis-Chalmers Co., Milwaukee, Wis.....	1905
SANZENBACHER, GEORGE	
Asst. Engr. and Supt. Dept. of Water, Newark, N. J....	1905

Date of Admission.

SAWYER, J. T.
Pres. Water-Works Company, Waverly, N. Y..... 1885

SCHULZ, C. F.
First Asst. Engr. Water-Works, 6002 Clinton Ave., N. W., Cleveland, Ohio..... 1906

SCHWERTFEGER, WILLIAM
Secretary City Water Board, Wheeling, W. Va..... 1906

SCOTT, WILLIAM G.
City Treas. and Mgr. Financial Dept. Water-Works, Winnipeg, Manitoba, Canada..... 1903

SEARS, WALTER
Chief Engr. Aqueduct Commission, 280 Broadway, New York, N. Y..... 1906

SENIOR, SAMUEL PALMER
Supt. and Engr. Bridgeport Hydraulic Co., Bridgeport, Connecticut 1906

SHAW, BENJ. F.
Water Commissioner, Wilmington, Del..... 1906

SHAW, HORACE H.
Mgr. Municipal Water-Works Co., Portland, Me..... 1905

SHAW, WALTER A.
Engr. in Charge Chicago Water-Works, 325 City Hall, Chicago, Ill..... 1906

SHEPHERD, A. B.
Supt. Water Supply & Distribution, Pittsburg, Pa..... 1896

SHEPPARD, JAMES H.
Supt. City Water Co., Monongahela City, Pa..... 1903

SHEPPERD, F. W.
"Fire and Water Engineering," 126 Liberty St., New York, N. Y..... 1888

SHERRERD, MORRIS R.
Chief Engineer, Street & Water Commission, 128 Halsey St., Newark, N. J..... 1897

SHIELDS, W. S.
Con. Engr., 1715 Marquette Bldg., Chicago, Ill..... 1899

SIDELINGER, GEO. B.
Supt. Water-Works, Danville, Ill..... 1902

SIMIN, NICHOLAS P.
Con. Engr., 3 Razgulay, Moscow, Russia..... 1898

SIMPSON, LAWRENCE
Secy. Water Company, Memphis, Tenn..... 1898

SLOANE, D. M.
Sec. and Treas. Ohio Valley Water Co., 409 Lincoln Ave., Bellevue, Pa..... 1906

SLOCUM, CHARLES EGBERT
Supt. Belleville Deep Well Water Co., Belleville, Ill..... 1902

	Date of Admission
SLUYTER, E. W.	
Supt. Water-Works, Herkimer, N. Y.	1906
SMITH, ANTHONY P.	
Mechanical Engr., Newark, N. J.	1890
SMITH, ERASTUS G., PH. D.	
Professor Chemistry, Beloit, Wis.	1890
SMITH, H. L.	
Norfolk, Va.	1903
SMITH, J. WALDO	
Chief Engr., Commission of Additional Water Supply for New York City, 299 Broadway, New York, N. Y.	1898
SMITH, OWEN T.	
Supt. Water-Works, Freeport, Ill.	1893
SMITH, W. T.	
Water Commissioner, Du Bois, Pa.	1906
SNELL, GEORGE H.	
Water Comr. and Supt., Attleboro, Mass.	1906
*SNELL, JAMES R.	
Supt. Amsterdam Water-Works, Amsterdam, N. Y.	1906
SNOW, ARCHIE H.	
Supt. Water Company, Montclair, N. J.	1898
SNOW, F. H.	
Con. Engr., 1120 Tremont Bldg., Boston, Mass.	1899
SOPER, GEORGE A., PH. D.	
Engr. and Chemist, 29 Broadway, New York, N. Y.	1900
SPRENKEL, JOHN F.	
Gen'l. Mgr. York Water Co., York, Pa.	1901
STAPLES, GEO. T.	
Supt. Water-Works, 64 School St., Dedham, Mass.	1906
STERLING, JOE C.	
Supt. Water-Works, Monroe, Mich.	1903
STRASSER, J. M.	
Supt. Electric Light & Power Co., La Grange, Ill.	1896
STRAUSE, NATHAN	
Pres. Water-Works, Ashland, Ohio	1904
TALBOT, ARTHUR N.	
Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.	1894
TALBOTT, FRANK	
Supt., Sec. and Treas. Water-Works, Danville, Va.	1904
TAUBENHEIM, ULRICH E.	
Mgr. Water-Works, Archangel, Russia	1905
TAYLOR, JOHN T.	
Gen. Mgr. Water-Works, Beaver Falls, Pa.	1906

	Date of Admission.
TAYLOR, SAMUEL A.	
Con. and Constructing Engr., 900 Lewis Block, Pittsburg, Pennsylvania	1902
THOMAS, C. O.	
Pres. Water Co., Caro, Mich	1903
THOMAS, ROBT. J.	
Supt. Water-Works, Lowell, Mass	1900
THOMSEN, CARL M.	
Supt. Water-Works, Farmington, Mo	1906
TIGHE, JAMES L.	
City Engr., Holyoke, Mass	1889
TILDEN, JAMES A.	
Mechanical Engr., Hersey Mfg. Co., Boston, Mass	1889
TOAL, D. C.	
Editor "Water and Gas Review," 35 Warren St., New York, N. Y.	1903
TODD, WILLIAM	
Supt. Electric Light and Water-Works, Austin, Minn	1901
TOMLINSON, SAMUEL	
Dept. Ex-Engineer Water-Works, Municipal Engineer, Raffles Place, Singapore, S. S	1887
TORRENCE, KENNETH	
Chief Engr. Pumping Station, Logan and Atlantic Ave., Brooklyn, N. Y	1897
TOWNSEND, E. R.	
Hydraulic Engineer, 125 Monroe St., Chicago, Ill	1906
TRAUTWINE, JOHN C., JR.	
Civil Engr., 257 South Fourth St., Philadelphia, Pa	1896
TRAVIS, ISAAC N.	
Supt. Water-Works, Orange, N. J	1898
TUCKER, A. A.	
Supt. Mains, Water Department, Memphis, Tenn	1892
TUTTLE, ARTHUR S.	
Principal Asst. Engr. Board of Estimate and Apportionment, 277 Broadway, New York, N. Y	1906
VAN DUYNE, J. RALPH	
Asst. Engr. Dept. of Water, Newark, N. J	1905
VAN GILDER, L.	
Engr. and Supt. Water Dept., City Hall, Atlantic City, New Jersey	1906
VEACH, W. A.	
Manager Water-Works Company, Newark, Ohio	1896
VERNER, T. H.	
Supt. Water & Light Dept., McKeesport, Pa	1903
VOLKHARDT, WILLIAM	
Stapleton, N. Y	1902

	Date of Admission.
WAGNER, E. C.	
Supt. Water Company, Girardville, Pa	1906
WALL, E. E.	
Asst. Water Comr., 4220 McPherson St., St. Louis, Mo.	1904
WANNER, P. D.	
Pres. Newport Home Water Co., Reading, Pa	1891
WARDE, JOHN S.	
Supt. and Engr., Staten Island Water Supply Company, West New Brighton, N. Y	1892
*WARNER, B. M.	
Gen. Supt. Southern California Mountain Water Co., Union Bldg., San Diego, Cal	1906
*WARREN, GEORGE C.	
Pres. Board Water Commissioners, Saginaw, Mich	1905
WASTENEYS, HARDOLPH	
Chemist, Board Water-Works, Brisbane, Queensland, Australia	1906
WATKINS, THOMAS	
Mechanical Engr., Johnstown, Pa	1892
WATSON, WALTER L.	
Supt. Clear Spring Water Co., Catasaqua, Pa	1901
WAY, J. F.	
Supt. Water, Light and Power Co., Watertown, S. Dak.	1904
WEDDLE, NELSON, JR.	
Sec. Water Co., West Newton, Pa	1906
WEGMAN, EDWARD	
Care Aqueduct Commission, Room 213, 280 Broadway, New York, N. Y	1902
WEHR, ALBERT H.	
Sec. and Treas. Baltimore County Water and Electric Company, Baltimore, Md	1901
WELLING, ROBERT	
Supt. Water-Works, Covington, Ky	1905
WESTON, ROBERT SPURR	
Chemist and Bacteriologist, 14 Beacon St., Boston, Mass.	1898
WHEELER, GEN'L. ELBERT	
Treas. Knoxville (Tenn.) Water Co., 14 Beacon St., Boston, Mass.	1903
WHEELER, SAM	
Supt. Water Company, Ashland, Wis	1903
WHEELER, WILLIAM	
Con. Engineer, Concord, Mass	1906
WHIPPLE, GEO. C.	
Con. Engr., 220 Broadway, New York, N. Y	1904
WHITNEY, DR. GEO. F.	
Biologist, 44 Central Ave., East Orange, N. J	1904

Date of Admission.

*Wilcox, W. J.
Supt. San Jose Water Co., San Jose, Cal..... 1906

Wiles, C. W.
Supt., Sec. and Treas. Water-Works, Delaware, Ohio.. 1899

Wilkinson, J. H.
Supt. Water-Works, Bowling Green, Ky..... 1889

Williams, Gardner S.
Consulting Engr. and Professor of Civil, Hydraulic and Sanitary Engineering, University of Michigan, 207 New Engineering Bldg., Ann Arbor, Mich..... 1906

Williams, Howard L.
Supt. Water-Works, Luddington, Mich..... 1894

Williams, Pat. H.
Supt. Water-Works, Charlotte, N. C..... 1906

Wingfield, Nisbet
Consulting Engr., Augusta, Ga..... 1905

Wirt, R. D.
22 N. Fourth St., Philadelphia, Pa..... 1885

*Wisler, James M.
Supt. Water-Works, 1128 Woodville St., Toledo, Ohio.. 1906

Witherell, Frederick W.
Asst. Engr. Penna. Dept. Health, Room 168, State Capitol, Harrisburg, Pa..... 1906

Witmer, J. F.
Hydraulic and Sanitary Engr., Chapin Block, Buffalo, New York 1905

Wood, Jas. W.
Pres. Henderson Water Co., Henderson, N. C., care Tippett & Wood, Phillipsburg, N. J..... 1896

Wood, John H.
Sec. and Supt. Water-Works, Baton Rouge, La..... 1893

Wood, Walter
Pres. Milville (N. J.) Water Co., 400 Chestnut St., Philadelphia, Pa..... 1905

Woodburn, Wm. F.
1528 E. Berks St., Philadelphia, Pa..... 1903

Woodruff, Timothy
Supt. Water-Works, Bridgeton, N. J..... 1888

Woodward, Park
Gen'l Mgr. Water-Works, Atlanta, Ga..... 1896

Worrell, M. L.
Secy. and Treas. Water Company, Selma, Ala..... 1903

Wynne-Roberts, R. O.
M. Inst. C. E., F. R. San. Inst., Water Engineering, Capetown, South Africa..... 1903

	Date of Admission.
WRIGHT, MILLARD F.	
Supt. Water-Works, Butler, Pa	1890
YOUNG, EZRA P.	
Pres. Water Company, Edgeworth, Pa	1902
YOUNG, T. L.	
Supt. S. S. W.-W. Co., Chester, W. Va	1906

ASSOCIATE MEMBERS.

	Date of Admission.
ADDRESSOGRAPH CO.	
Mfgrs. Addressing Machines, 232 W. Van Buren, Chicago, Ill	1906
ALLIS-CHALMERS CO.	
Milwaukee, Wis.	1905
AMERICAN ASPHALTUM & RUBBER CO.	
Woman's Temple, Chicago, Ill	1903
AMERICAN PIPE MANUFACTURING CO., THE	
112 North Broad St., Philadelphia, Pa	1903
AMERICAN STEEL AND WIRE CO.	
The Rookery, Chicago, Ill	1903
AMERICAN VALVE AND METER CO.	
324 Pike Bldg., Cincinnati, Ohio	1900
ATLAS PORTLAND CEMENT CO., THE	
30 Broad St., New York, N. Y	1906
BABCOCK & WILCOX BOILER CO.	
85 Liberty St., New York, N. Y	1896
BINGHAM & TAYLOR	
Church and Jackson Sts., Buffalo, N. Y	1882
BOOTH, L. M., COMPANY	
Water Softening and Purification, 136 Liberty St., New York, N. Y	1906
BOURBON COPPER AND BRASS WORKS CO.	
618 East Front St., Cincinnati, Ohio	1889
BUFFALO METER CO.	
290 Terrace, Buffalo, N. Y	1905
BUILDERS' IRON FOUNDRY	
9 Codding St., Providence, R. I	1901
CENTRAL FOUNDRY CO.	
116 Nassau St., New York, N. Y	1903
CHAPMAN VALVE MANUFACTURING COMPANY	
Indian Orchard, Mass	1884
CHICAGO BRIDGE & IRON COMPANY	
Builders of Water Towers and Standpipes, 1402, 105th, cor. Throop Sts., Chicago, Ill	1898
CLOW, J. B., & SONS	
Harrison and Franklin Sts., Chicago, Ill	1885
COCHRANE CHEMICAL CO.	
Mfgrs. Alum, 55 Kilby St., Boston, Mass	1906
COFFIN VALVE CO.	
Dorchester, Boston, Mass	1906
COLORADO FUEL & IRON CO.	
Denver, Colo	1897

	Date of Admission.
COLUMBUS BOARD OF PUBLIC SERVICE	
Water Dept., Columbus, Ohio	1887
COLUMBUS METER SEAL MFG. CO., THE.	
136 E. Main St., Columbus, Ohio	1904
COOK WELL COMPANY	
15 S. Fourth St., St. Louis, Mo	1894
COSTELLO, GEO. M.	
Pres. Cancos Mfg. Co., Mfgrs. Steam Packing, 146 N. Second St., Philadelphia, Pa	1906
DAY, CHARLES R.	
Sales Agent The Midvale Steel Co., 111 Broadway, New York, N. Y.	1904
DAYTON BOARD OF PUBLIC SERVICE	
Water Dept., Dayton, Ohio	1892
DRESSER, S. R.	
Mfgr. Pipe Couplings and Sleeves, Bradford, Pa	1904
DRUMMOND, M. J., & CO.	
Cast Iron Pipe, 182 Broadway, New York, N. Y	1895
EAST JERSEY PIPE CO., THE	
71 Broadway, New York, N. Y	1906
EDDY VALVE MANUFACTURING CO.	
Waterford, N. Y	1886
ELLIS-FORD MANUFACTURING CO.	..
101 Atwater St., East, Detroit, Mich	1905
EXCELSIOR WOODEN PIPE CO.	
Manufacturers and Builders of Wooden Stave Pipe, 220 Broadway, New York, N. Y	1906
FAIRBANKS COMPANY, THE	
Broome and Elm Sts., New York, N. Y	1905
FARNAN BRASS WORKS	
23 Centre St., Cleveland, Ohio	1892
GAMEWELL FIRE ALARM TELEGRAPH CO., THE	
19 Barclay St., New York, N. Y	1903
GENERAL CHEMICAL CO.	
Manufacturers of Filter Alum and Dealers in Sulphur, 135 Adams St., Chicago, Ill	1902
GENERAL FIRE EXTINGUISHER COMPANY	
Executive Offices, Union Trust Bldg., Providence, R. I	1905
GILLESPIE, T. A.	
Pres. The T. A. Gillespie Co., 71 Broadway, New York, N. Y.	1904
GLAUBER BRASS MFG. CO.	
1643-1677 Superior St., Cleveland, Ohio	1904
GOULD, NORMAN	
Secretary The Goulds' Mfg. Co., Seneca Falls, N. Y	1906

Date of Admission.

GREAT FALLS (MONT.) WATER DEPARTMENT
Great Falls, Mont., Geo. W. Bird, City Engr..... 1904
HAYS MANUFACTURING COMPANY
Erie, Pa..... 1882
HERSEY MANUFACTURING COMPANY
South Boston, Mass..... 1887
HOGE & SWIFT
Manufacturers' Agents, Portland, Oregon..... 1904
HUDSON CONTRACTING CO.
Contractors for Cleaning Water Mains, 27 William St., New York, N. Y..... 1906
ILLINOIS MALLEABLE IRON COMPANY
30 W. Monroe St., Chicago, Ill..... 1890
INTERNATIONAL STEAM PUMP CO.
Water-works Machinery, 114 Liberty St., New York, N. Y.. 1901
JACKSON FILTER MFG. CO.
Chemical Bldg., St. Louis, Mo..... 1904
KELLOGG, E. H., & CO.
243 South St., New York, N. Y..... 1886
KENNEDY, DANIEL
Pres. Kennedy Valve Manufacturing Company, 57 Beekman St., New York, N. Y..... 1895
LEAD LINED IRON PIPE CO., THE
Wakefield, Mass..... 1898
LENNOX MACHINE COMPANY
Water Tapping Machine, Marshalltown, Iowa..... 1896
LONDON WATER BOARD
London, Canada 1892
LUDLOW VALVE MANUFACTURING COMPANY
Troy, N. Y..... 1882
MERRILL, WM. B., & CO.
Metallic Packing, Boston, Mass..... 1906
MODERN IRON WORKS
Quincy, Ill..... 1905
MUELLER, H., MANUFACTURING COMPANY
Decatur, Ill..... 1882
NATIONAL BRASS & METAL COMPANY
256 S. Third St., Minneapolis, Minn..... 1904
NATIONAL METER COMPANY
84-86 Chambers St., New York, N. Y..... 1882
NEPTUNE METER CO.
120 Liberty St., New York, N. Y..... 1894
NEW YORK CONTINENTAL JEWELL FILTRATION CO.
15 Broad St., New York, N. Y..... 1888
NORFOLK CITY WATER DEPARTMENT
Norfolk, Va. 1889

	Date of Admission.
PENNSYLVANIA SALT MANUFACTURING CO., THE 115 Chestnut St., Philadelphia, Pa	1903
PITOMETER COMPANY, THE 220 Broadway, New York, N. Y	1906
PITTSBURG FILTER MANUFACTURING COMPANY Farmers' Bank Bldg., Pittsburg, Pa	1905
PITTSBURG METER COMPANY East Pittsburg, Pa	1898
PLATT IRON WORKS CO. Pumping Engines, Dayton, Ohio	1901
PLEUGER & HENGER MANUFACTURING COMPANY St. Louis, Mo	1896
RENSSELAER MANUFACTURING COMPANY Troy, N. Y	1890
ROSS VALVE CO. Oakwood Ave., Troy, N. Y	1891
RYERSON, JOSEPH T., & SON Iron and Steel Merchants and Special Agents, 18 Milwaukee Ave., Chicago, Ill	1902
SAFETY METER LOCK CO. M. A. Corbett, Mgr., Columbus, Ohio	1905
SEAGRAVE, F. S. Hydraulic Cut-off Valves, Detroit, Mich	1906
SMITH, ANTHONY P., MANUFACTURING CO. Newark, N. J	1897
THOMSON METER COMPANY 79 Washington St., Brooklyn, N. Y	1891
TOD, THE WILLIAM, CO. High Duty Pumping Engines, Youngstown, Ohio	1904
TRENTON WATER WORKS Trenton, N. J	1898
UNION WATER METER CO. Worcester, Mass	1882
UNITED STATES CAST IRON PIPE & FOUNDRY COMPANY 217 La Salle St., Chicago, Ill	1902
UNITED WATER IMPROVEMENT COMPANY 1420 Pennsylvania Bldg., Philadelphia, Pa	1906
VAN WINKLE, WALTER H. Pres. and Gen. Mgr. Water-Works Equipment Co., 180 Broadway, New York, N. Y	1906
WALWORTH MANUFACTURING COMPANY 132 Federal St., Boston, Mass	1891
WHITALL, W. VAN R. Pres. Hydro-Carbon Co., 320 Wazee St., Denver, Colo	1904

	Date of Admission.
WOOD, R. D., & Co.	
400 Chestnut St., Philadelphia, Pa.....	1884
YEISER, L. B.	
Salesman for the Sanitary Company, Cleveland, Ohio...	1904

SUMMARY.

Honorary Members	7
Active Members	504
Associate Members	85
Total.....	596

LIST OF MEMBERS ARRANGED GEOGRAPHICALLY

ALABAMA.—Total, 2.

ACTIVE.

HAZELHURST, J. N., *Mobile.*
WORRELL, M. L., *Selma.*

ARIZONA.—Total, 2.

ACTIVE.

CONLON, THOS., *Tucson.*
GICLAS, ELI, *Flagstaff.*

ARKANSAS.—Total, 1.

ACTIVE.

ROSAMOND, S. J., *Fort Smith.*

CALIFORNIA.—Total, 7.

ACTIVE.

ALLIN, T. D., *Pasadena.*
BOOKER, GEO. E., *San Francisco.*
HALL, J. W., *Stockton.*
HUNTER, T. B., *Monterey.*
LECONTE, L. J., *Oakland.*
WARNER, B. M., *San Diego.*
WILCOX, W. J., *San Jose.*

COLORADO.—Active, 7; Associate, 2. Total, 9.

ACTIVE.

CASE, E. W., *Colorado Springs.*
DUNBAUGH, GEO. J., *Pueblo.*
HOPKINS, J. A., *Colorado Springs.*
MCCUE, W. F., *Denver.*
PRIDDY, CHAS. N., *Leadville.*
PRINCE, GEO. T., *Denver.*
ROBINSON, WM. P., *Denver.*

ASSOCIATE.

COLORADO FUEL & IRON CO., *Denver.*
WHITALL, W. VAN R., *Denver.*

CONNECTICUT.—Total, 5.

ACTIVE.

BROOKS, ISAAC W., *Torrington.*
HATCH, EDWARD L., *Stamford.*
HAYDEN, N. W., *Windsor.*
NETTLETON, CHAS. H., *Derby.*
SENIOR, SAM'L P., *Bridgeport.*

DELAWARE.—Total, 4.

ACTIVE.

BOND, JOS. A., *Wilmington.*
HATTON, T. C., *Wilmington.*
LEISEN, THEO. A., *Wilmington.*
SHAW, B. F., *Wilmington.*

FLORIDA.—Total, 5.

ACTIVE.

CAMPBELL, J. A., *Ocala.*
DEARBORN, H. M., *Fernandina.*
ELLIS, R. N., *Jacksonville.*
MACGONIGLE, J. N., *Miami.*
PITT, B. R., *Pensacola.*

GEORGIA.—Total, 6.

ACTIVE.

CAMPBELL, C. H., *Atlanta.*
CLAYTON, R. M., *Atlanta.*
HOAGLAND, I. G., *Atlanta.*
RAPP, W. M., *Atlanta.*
WINGFIELD, N., *Augusta.*
WOODWARD, PARK, *Atlanta.*

ILLINOIS—Honorary, 1; Active, 44; Associate, 11. Total, 56.

HONORARY.

FOSTER, J. F., *Chicago.*

ACTIVE.

ALFORD, J. W., *Chicago.*
AMSBARY, F. C., *Champagne.*
ARTINGSTALL, S. G., *Chicago.*
BAKER, H. S., *Chicago.*
BANCROFT, P. T., *Rock Island.*
BARTOW, EDWARD, *Urbana.*
BROWN, C. ARTHUR, *Chicago.*
BROWN, C. S., *Chicago.*
BURNS, T. W., *Fairbury.*
CALPINS, W. N., *Chicago.*
CLARK, H. W., *Mattoon.*
COBB, H. C., *Kankakee.*
COLE, JOHN A., *Chicago.*
ERICKSON, J. E., *Chicago.*
GANNON, T. W., *Cairo.*
GUILFORD, A. J., *Chicago.*
HARDY, A. W., *Chicago.*
HORNER, C. M., *E. St. Louis.*
HORTON, H. E., *Chicago.*
HUGGINS, D. E., *Streator.*
JEWELL, W. M., *Chicago.*
JEFFERIS, L. M., *E. St. Louis.*
KEELER, H. E., *Chicago.*
LAUTZ, HENRY, *Pekin.*
LEVERING, W. A., *Chicago.*
LITTERER, F., *Decatur.*
LUCAS, F. L., *Pontiac.*
MACDONALD, EMMET, *Lincoln.*
MAURY, D. H., *Peoria.*
MEAD, D. W., *Chicago.*
NOURSE, H. O., *Chicago.*
PARKIN, R. R., *Elgin.*
PHILLIPS, T. C., *Chicago.*
PRENTICE, A. T., *Chicago.*
PRINCE, EDWARD, *Quincy.*
RUTHRAUFF, H., *Decatur.*
SHAW, W. A., *Chicago.*
SHIELDS, W. A., *Chicago.*
SIDELINGER, G. B., *Danville.*
SLOCUM, C. E., *Belleville.*
SMITH, O. T., *Freeport.*
STRASSER, J. M., *LaGrange.*
TALBOT, A. N., *Urbana.*
TOWNSEND, E. R., *Chicago.*

ASSOCIATE.

ADDRESSOGRAPH CO., *Chicago.*
AMER. ASPHALTUM & RUBBER CO., *Chicago.*
AMER. STEEL & WIRE CO., *Chicago.*
CHICAGO BRIDGE & IRON CO., *Chicago.*
CLOW, J. B. & SON, *Chicago.*
GENERAL CHEMICAL CO., *Chicago.*
ILL. MALLEABLE IRON CO., *Chicago.*
MODERN IRON WORKS, *Quincy.*
MUELLER, H. MFG. CO., *Decatur.*
RYERSON, JOS. T. & SON, *Chicago.*
U. S. CAST IRON PIPE & FDY. CO., *Chicago.*

INDIANA.—Total, 11.

ACTIVE.

Brown, C. C., *Indianapolis.*
Davis, F. A. W., *Indianapolis.*
Dill, H. A., *Richmond.*
Ford, E. H., *Hartford City.*
Gwinn, Dow. R., *Terre Haute.*
Heeger, E. I., *Evansville.*
Hulley, E., *Marion.*
Loomis, E. L., *Valparaiso*
McGrath, R. H., *Lafayette.*
McNamee, T. W., *Wabash.*
Peck, J. W., *Evansville.*

IOWA.—Active, 17; Associate, 1. Total, 18.

ACTIVE.

Barker, W. H., *Sioux City.*
Berry, J. P., *Waterloo.*
Carlin, P., *Iowa City.*
Chatham, J., *Iowa City.*
Donahue, J. P., *Davenport.*
Ellwanger, J., *Dubuque.*
Fitch, W. P., *Mason City.*
Fox, C. J., *Cedar Rapids.*
Hart, E. W., *Council Bluffs.*
Healey, G. B., *Sioux City.*
Henderson, C. R., *Waterloo.*
Hooper, T. N., *Davenport.*
Kastberg, K. C., *Boone.*
McArthur, Arthur, *Dubuque.*
Molis, Wm., *Muscatine.*
Ryder, P. F., *Dubuque.*
Salmon, F. W., *Burlington.*

ASSOCIATE.

Lennox Machine Co., *Marshalltown.*

KANSAS.—Total, 3.

ACTIVE.

Bishop, J. L., *Salina.*
Chisham, J. M., *Atchison.*
Riley, Lee, *Kansas City.*

KENTUCKY.—Total, 8.

ACTIVE.

Burnett, M., *Paducah.*
Glazier, W. L., *Newport.*
Glore, W. H., *Covington.*
Hermany, C., *Louisville.*
Martin, H. P., *Owensboro.*
Patton, W. A., *Catlettsburg.*
Welling, R., *Covington.*
Wilkinson, J. H., *Bowling Green.*

LOUISIANA.—Total, 3.

ACTIVE.

Gardner, L. H., *New Orleans.*
Milner, W. J., *New Orleans.*
Wood, J. H., *Baton Rouge.*

MAINE.—Active, 9; Associate, 1. Total, 10.

ACTIVE.

Bowker, C. L., *Brunswick.*
Eaton, H. D., *Waterville.*
Fenn, C. W., *Portland.*
Merrill, A. S., *Bath.*
Mixer, C. A., *Rumford Falls.*
Payson, E. R., *Portland.*

GETCHELL, W. B., *Augusta.*
MANLEY, S. C., *Augusta.*
SHAW, H. H., *Portland.*

ASSOCIATE.

ATLAS PORTLAND CEMENT CO., *Portland.*

MARYLAND.—Total, 3.

ACTIVE.

HARLOW, J. H., *Conowingo.*
QUICK, A. M., *Baltimore.*
WEHR, A. H., *Baltimore.*

MASSACHUSETTS.—Active, 27; Associate, 8. Total, 35.

ACTIVE.

BANCROFT, L. M., *Reading.*
BARBOUR, F. A., *Boston.*
BLAKE, E. M., *Boston.*
BRACKETT, D., *Boston.*
ELLSWORTH, E. A., *Holyoke.*
FOSS, W. E., *Boston.*
FRENCH, A. N., *Hyde Park.*
FRENCH, E. V., *Boston.*
FULLER, F. L., *Boston.*
GLOVER, A. S., *Boston.*
HODGSON, J. S., *Wellington.*
KIMBALL, F. C., *Boston.*
KINNICUTT, L. P., *Worcester.*
LOCHRIDGE, E. E., *Springfield.*
LOCKE, J. W., *Brockton.*
METCALF, L., *Boston.*
MULLHALL, J. F. J., *Boston.*
SNELL, G. H., *Attleboro.*
SNOW, F. H., *Boston.*
STAPLES, G. T., *Dedham.*
THOMAS, R. J., *Lowell.*
TIGHE, J. L., *Holyoke.*
TILDEN, JAMES O., *Boston.*
WESTON, R. S., *Boston.*
WHEELER, GEN. E., *Boston.*
WHEELER, WM., *Concord.*
WOODBURN, W. F., *Springfield.*

ASSOCIATE.

CHAPMAN VALVE MFG. CO., *Indian Orchard.*
COCHRANE CHEMICAL CO., *Boston.*
COFFIN VALVE CO., *Boston.*
HERSEY MFG. CO., *Boston.*
LEAD LINED IRON PIPE CO., *Wakefield.*
MERRILL, W. B. & CO., *Boston.*
UNION WATER METER CO., *Worcester.*
WALWORTH MFG. CO., *Boston.*

MICHIGAN.—Active, 21; Associate, 2. Total, 23.

ACTIVE.

ANDERSON, L. W., *Grand Rapids*
BURTON, H., *Port Huron.*
CAHILL, S. A., *Manistee.*
CAMPBELL, J. J., *Menominee.*
CROLL, E. A., *Iron Mountain.*
DEVINE, P. H., *Ishpeming.*
DEYOUNG, JAS., *Holland.*
DUNBAR, E. L., *Bay City.*
HOUSTON, GEO., *Kalamazoo.*
HUBBELL, C. W., *Detroit.*
HUTZELL, T. F., *Ann Arbor.*
MONROE, H. G., *Pontiac.*
REED, W. F., *Kalamazoo.*
STERLING, J. C., *Monroe.*
THOMAS, C. O., *Caro.*
WARREN, G. C., *Saginaw.*

Gould, U., *Detroit.*
Hale, A. K., *Ann Arbor.*
Holmes, A. E., *Grand Rapids.*
Williams, G. S., *Ann Arbor.*
Williams, H. L., *Luddington.*

ASSOCIATE.

Ellis-Ford Mfg. Co., *Detroit.*
Seagrave, F. S., *Detroit.*

MINNESOTA.—Honorary, 1; Active, 10; Associate, 1. Total, 12.

HONORARY.

Bement, R. B. C.

ACTIVE.

Cappelen, F. W., *Minneapolis.*
Case, L. N., *Duluth.*
Caulfield, John, *St. Paul.*
Connor, F. J., *Faribault.*
Fanning, J. T., *Minneapolis.*
Gray, H. B., *Minneapolis.*
Lovell, W. D., *Minneapolis.*
McConnell, J. H., *Minneapolis.*
McGilvray, T. H., *Duluth.*
Todd, Wm., *Austin.*

ASSOCIATE.

National Brass & Metal Co., *Minneapolis.*

MISSISSIPPI.—Total, 3.

ACTIVE.

Fewell, J. H., *Jackson.*
Jones, Burke, *Hattiesburg.*
Lorenz, Jno., *Jackson.*

MISSOURI.—Honorary, 2; Active, 15; Associate, 3. Total, 20.

HONORARY.

Holman, M. L., *St. Louis.*
Watts, Sylvester, *St. Louis.*

ACTIVE.

Adkins, B. C., *St. Louis.*
Anderson, L. W., *Kansas City.*
Andrews, L. P., *Sedalia.*
Binder, F. C., *Jefferson City.*
Cullinane, J. R., *St. Louis.*
Goodwin, W. G., *Kansas City.*
Hibbeler, H. D., *Washington.*
High, S. Y., *Kansas City.*
Lafavor, W. L., *Springfield.*
Miller, J. A., *Louisiana.*
Monfort, W. F., *St. Louis.*
Meyers, G. M., *Kansas City.*
Rolfe, W. E., *St. Louis.*
Thomsen, C. M., *Farmington.*
Wall, E. E., *St. Louis.*

ASSOCIATE.

Cook Well Co., *St. Louis.*
Jackson Filter Mfg. Co., *St. Louis.*
Pleuger & Henger Mfg. Co., *St. Louis.*

MONTANA.—Active, 3; Associate, 1. Total, 4.

ACTIVE.

CARROLL, E., *Butte.*
McLEOD, T. T., *Missoula.*
ROBLIN, F. B., *Kalispell.*

ASSOCIATE.

GREAT FALLS WATER DEPT., *Great Falls.*

NEBRASKA.—Total, 4.

ACTIVE.

CARLSON, J. A., *Stromburg.*
DEFFENBAUGH, J. M., *Lincoln.*
FAIRFIELD, E. M., *Omaha.*
KOENIG, A. C., *Omaha.*

NEVADA.—Total, 1.

ACTIVE.

ROWE, C. E., *Goldfield.*

NEW HAMPSHIRE.—Total, 1.

ACTIVE.

BUNKER, G. C., *Littleton.*

NEW JERSEY.—Active, 31; Associate, 2. Total, 33.

ACTIVE.

BASSETT, C. P., *Summit.*
BAUMAN, C. V., *Newark.*
BURLEIGH, J. J., *Camden.*
CONARD, W. R., *Burlington.*
COOK, J. H., *Paterson.*
CORR, A. S., *Phillipsburg.*
CUDDEBACK, A. W., *Paterson.*
DEIGNAN, J. E., *East Orange.*
EGGERS, A. F., *Newark.*
ELEY, FRANK, *Bayonne.*
FRENCH, D. W., *Weehawken.*
GARRISON, R. H., *Vineland*
GEDNEY, J. D., *East Orange.*
GRIFFIN, W. J., *Arlington.*
HARRISON, E. W., *Jersey City.*
HOLLINGSWORTH, R., *Camden.*
JONES, A. J., *New Brunswick.*
KELLOGG, R. M., *Metuchen.*
McDERMOTT, L. C., *East Orange.*
PHILLIPS, G. H., *Newark.*
REIMER, A. A., *East Orange.*
SANZENBACHER, G., *Newark.*
SHERRERD, M. R., *Newark.*
SMITH, A. P., *Newark.*
SNOW, A. E., *Montclair.*
TRAVIS, I. N., *Orange.*
VAN DUYNE, J. R., *Newark.*
VAN GILDER, L., *Atlantic City.*
WHITNEY, D. F., *East Orange.*
WOOD, J. W., *Phillipsburg.*
WOODRUFF, T., *Bridgeton.*

ASSOCIATE.

SMITH, A. P., MFG. CO., *Newark.*
TRENTON WATER WORKS, *Trenton.*

NEW MEXICO.—Total, 2.

ACTIVE.

HOBBS, A. L., *Raton.*
KING, A. L., *Alamogorda.*

NEW YORK.—Honorary, 1; Active, 78; Associate, 27. Total, 106.

HONORARY.

HOLLY, IRA A., *New York.*

ACTIVE.

BABCOCK, S. E., *Utica.*
BACOT, R. C., *Port Chester*
BAKER, M. N., *New York.*
BASSETT, G. B., *Buffalo.*
BENNETT, T. H., *Oswego.*
BETTS, C. R., *Far Rockaway.*
BLOSSOM, F., *New York.*
BOARDMAN, A. E., *New York.*
BOGART, J. C., *New York.*
BRIGHTMAN, H. I., *New York.*
BUSH, J. C., *Binghamton.*
CAIRD, J. M., *Troy.*
CALDWELL, J. H., *Troy.*
COLE, E. S., *New York.*
COLE, W. W., *Elmira.*
COOK, F. S., *New York.*
CRANDALL, W. S., *New York.*
DAVY, T. W., *Middletown.*
DRISCOLL, M. A., *Haverstraw.*
DRUMMOND, M. J., *Green Island.*
DUNHAM, H. F., *New York.*
FARLEY, J. M., *White Plains.*
FISHER, E. A., *Rochester.*
FITZPATRICK, J. R., *New York.*
FOLWELL, A. P., *New York.*
FOSTER, E. H., *New York.*
FUERTES, J. H., *New York.*
FULLER, G. W., *New York.*
GALLAGHER, J. F., *Kingston.*
GIESLER, A., *New York.*
GOODELL, J. M., *New York.*
GUBELMAN, F. J., *New York.*
HAGUE, C. A., *New York.*
HAZEN, A., *New York.*
HEERMANS, H. C., *Corning.*
HERING, R., *New York.*
HERSCHEL, C., *New York.*
HILL, W. R., *Brooklyn.*
HILLABRANDT, L., *Johnstown.*
HODGKINS, H. C., *Syracuse.*
KELLEY, J. C., *New York.*
KELLEY, N. J., *Buffalo.*
KLINGBERG, W., *Kingston.*
KUICHLING, E., *New York.*
KNUDSON, A. A., *New York.*
LITTLE, B. C., *Rochester.*
LOCKWOOD, A., *Jamaica.*
LONGYEAR, O. C., *Brooklyn.*
LORD, H. A., *Ogdensburg.*
LYON, H. L., *Buffalo.*
MCCARTHY, D. B., *Waterford.*
MCKIM, R. A., *New York.*
MASON, W. P., *Troy.*
MERRITT, D. S., *Tarrytown.*
MILLIGAN, R. E., *New York.*
NEVILLE, T. J., *Rochester.*
NEWTON, H. D., *Norwich.*
PEENE, E. L., *Yonkers.*
POTTS, C., *New York.*
POWELL, S. T., *Troy.*
REAGAN, J. F., *Utica.*
REYER, G., *Mt. Vernon.*
ROSS, C. H., *Waterloo.*
SAWYER, J. T., *Waverly.*
SEARS, W., *New York.*
SHEPPERD, F. W., *New York.*
SLUYTER, E. W., *Herkimer.*
SMITH, J. W., *New York.*
SNELL, J. R., *Amsterdam.*
SOPER, G. A., *New York.*
TOAL, D. C., *New York.*
TORRENCE, K., *Brooklyn.*
TUTTLE, A. S., *New York.*
VOLKHARDT, W., *Stapleton.*
WARDE, J. S., *Brighton.*
WEGMAN, E., *New York.*
WHIPPLE, G. C., *New York.*
WHITMER, J. F., *Buffalo.*

ASSOCIATE.

BABCOCK & WILCOX BOILER CO., *New York.*
GOULD, N., *Seneca Falls.*

Bingham & Taylor, *Buffalo.*
Booth, L. M., Co., *New York.*
Buffalo Meter Co., *Buffalo.*
Central Foundry Co., *New York.*
Day, C. R., *New York.*
Drummond, M. J. & Co., *New York.*
East Jersey Pipe Co., The, *New York.*
Eddy Valve Mfg. Co., *Waterford.*
Excelsior Wooden Pipe Co., *New York.*
Fairbanks Co., The, *New York.*
Gamewell Fire Alarm Telegraph Co., The, *New York.*
Gillespie, T. A., *New York.*
Hudson Contracting Co., *New York.*
International Steam Pump Co., *New York.*
Kellogg, E. H. & Co., *New York*
Kennedy, Dan'l, *New York.*
Ludlow Valve Mfg. Co., *Troy.*
National Meter Co., *New York.*
Neptune Meter Co., *New York.*
New York Continental Jewell Filtration Co., *New York.*
Pitometer Co., *New York.*
Rensselaer Mfg. Co., *Troy.*
Ross Valve Co., *Troy.*
Thomson Meter Co., *Brooklyn.*
Van Winkle, W. H., *New York.*

NORTH CAROLINA.—Total, 9.

ACTIVE.

Bain, E. B., *Raleigh.*
Knox, H. E., *Charlotte.*
Ludlow, J. L., *Winston-Salem.*
McCormick, W. T., *Charlotte.*
Michie, J. C., *Durham.*
Milton, R. H., *Reidsville.*
Robertson, W. F., *Wilmington.*
Rutledge, G. H., *Concord.*
Williams, P. H., *Charlotte.*

NORTH DAKOTA.—Total, 1.

ACTIVE.

Russell, W. S., *Dickinson.*

OHIO.—Active, 30; Associate, 11; Total, 41.

ACTIVE.

Beardsley, J. C., *Cleveland.*
Belcher, D. M., *Columbus.*
Bemis, E. W., *Cleveland.*
Boeh, W. H., *Cincinnati.*
Bolger, F. E., *Springfield.*
Brotherton, C. F., *Ashtabula.*
Chapin, L. E., *Canton.*
Clark, D. H., *Ironton.*
Cook, T. R., *Toledo.*
Dow, A. R., *Salem.*
Ferguson, W. K., *Springfield.*
Gerrish, W. B., *Oberlin.*
Gregory, J. H., *Columbus.*
Harvey, L., *Conneaut.*
Heisler, C. L., *St. Mary's.*
Hill, J. W., *Cincinnati.*
Hornung, G., *Cincinnati.*
Kingsley, M. W., *Cleveland.*
Latta, S. M., *Akron.*
McAlpine, *Columbus.*
McDargh, H. J., *Dayton.*
Monjeau, C., *Middletown.*
Ohliger, L. B., *Canton.*
O'Shaughnessy, J., *Columbus.*
Schultz, C. F., *Cleveland.*
Sloane, D. M., *Bellevue.*
Strause, N., *Ashland.*
Veach, W. A., *Newark.*
Wiles, C. W., *Delaware.*
Wisler, J. M., *Toledo.*

ASSOCIATE.

AMER. VALVE & METER CO., *Cincinnati.*
BOURBON COPPER & BRASS WKS., *Cincinnati.*
COLUMBUS BOARD OF PUBLIC SERVICE, *Columbus.*
COLUMBUS METER SEAL MFG. CO., *Columbus.*
DAYTON BOARD OF PUBLIC SERVICE, *Dayton.*
FARNAN BRASS WORKS, *Cleveland.*
GLAUBER BRASS MFG. CO., *Cleveland.*
PLATT IRON WORKS, *Dayton.*
SAFETY METER LOCK CO., *Columbus.*
TOD, THE WM. CO., *Youngstown*
YEISER, L. B., *Cleveland.*

OREGON.—Active, 1; Associate, 1. Total, 2.

ACTIVE.

GATES, H. V., *Hillsboro.*

ASSOCIATE.

HOGE & SWIFT, *Portland.*

PENNSYLVANIA.—Active, 65; Associate, 9. Total, 74.

ACTIVE.

AFFLECK, J. A., *Harrisburg.*
BOARDMAN, W. H., *Philadelphia.*
CLARK, J. V., *Washington.*
CONLIN, F., *Bethlehem.*
CROWTHER, H., *Philadelphia.*
DEERY, J. J., *Philadelphia.*
DOWNES, J. R., *Harrisburg.*
DURLIN, W. B., *Erie.*
ELBERT, E., *Reading.*
EVANS, J. R., *Pottstown.*
FELIX, G. H., *Reading.*
FORBES, M., *Greensburg.*
FRAILEY, E. F., *Lancaster.*
FULLER, A. J., *Philadelphia.*
GAILEY, S. A., *Altoona.*
GOODNOW, W. T., *Sayre.*
HAND, F. L., *Philadelphia.*
HARBSTER, M., *Reading.*
HARLOW, G. R., *Edgewood.*
HIGBEE, I. M., *Lewisburg.*
HOLMES, A. G., *Pittsburg.*
HUNTER, W. J., *Pittsburg.*
HUTH, F., *Nazareth.*
HUTTON, G. H., *Harrisburg.*
JACKSON, R. A., *Norristown.*
SMITH, W. T., *Dubois.*
KENNEDY, G. C., *Harrisburg.*
KUHN, W. S., *Pittsburg.*
LANDES, J. D., *Mechanicsburg.*
LOETZER, C. E., *Sayre.*
MCCABE, D. H., *Monessen.*
MCCONNELL, W. C., *Shamokin.*
MCWILLIAMS, C. Q., *Shamokin.*
MAIGNEN, P. A., *Philadelphia.*
MARPLE, M. W., *Scranton.*
MATHER, E., *Harrisburg.*
MELLON, T. A., *Pittsburg.*
MERCER, E. A., *Chester.*
MEYERS, A. H., *Columbia.*
MILLER, J. T., *Pittsburg.*
MURPHY, H., *Philadelphia.*
NEUBLING, E. L., *Reading.*
PENNEY, C. L., *Edgewood Park.*
POLLARD, W. D., *Pottsville.*
PRENTER, M., *Pittsburg.*
PUGH, M. R., *Philadelphia.*
PURDY, J. H., *Pittsburg.*
ROHRBACH, W. R., *Sunbury.*
SHEPHERD, A. B., *Pittsburg.*
SHEPPARD, J. H., *Monongahela City.*
WATKINS, T., *Johnstown.*

SPRENKEL, J. F., *York.*
TAYLOR, J. T., *Beaver Falls.*
TAYLOR, S. A., *Pittsburg.*
TRAUTWINE, J. C., JR., *Philadelphia*
VERNER, T. H., *McKeesport.*
WAGNER, E. C., *Girardville.*
WANNER, P. D., *Reading.*
WATSON, W. L., *Catasaqua.*
WEDDEL, N., *West Newton.*
WIRT, R. D., *Philadelphia.*
WITHERELL, F. W., *Harrisburg.*
WOOD, R. D., *Philadelphia.*
WRIGHT, M. F., *Butler.*
YOUNG, E. P., *Edgeworth.*

ASSOCIATE.

AM. PIPE MFG. CO., *Philadelphia.*
COSTELLO, G. M., *Philadelphia.*
DRESSER, S. R., *Bradford.*
HAYS MFG. CO., *Erie.*
PENN. SALT MFG. CO., *Philadelphia.*
PITTSBURG FILTER MFG. CO., *Pittsburg.*
PITTSBURG METER CO., *Pittsburg.*
UNITED WATER IMPROVEMENT CO., *Philadelphia.*
WOOD, R. D. & CO., *Philadelphia.*

RHODE ISLAND.—Total, 2.

ASSOCIATE.

BUILDERS' IRON FOUNDRY, *Providence.*
GENERAL FIRE EXTINGUISHER CO., *Providence.*

SOUTH CAROLINA.—Total, 2.

ACTIVE.

CHISOLM, E. N., *Columbia.*
DIVEN, J. M., *Charleston.*

SOUTH DAKOTA.—Total, 1.

ACTIVE.

WAY, J. F., *Warrentown.*

TENNESSE.—Total, 5.

ACTIVE.

AHERN, J. T., *Nashville.*
AIKEN, H. M., *Knoxville.*
OMBERG, J. A., *Memphis.*
SIMPSON, L., *Memphis.*
TUCKER, A. A., *Memphis.*

TEXAS.—Total, 6.

ACTIVE.

ALDERMAN, C. L., *Big Springs.*
BRACKENRIDGE, G. W., *San Antonio.*
CAIN, W. L., *Tyler.*
CALHOUN, H. L., *Fort Worth.*
KNOX, W. F., *Tyler.*
NEWTON, S. O., *Weatherford.*

UTAH.—Total, 2.

ACTIVE.

HINES, F. L., *Salt Lake City.*
MCCORKINDALE, W. J., *Salt Lake City.*

VERMONT.—Total, 1.

ACTIVE.

HAWKES, W. E., *Bennington.*

VIRGINIA.—Active, 9; Associate, 1. Total, 10.

ACTIVE.

BOLLING, C. E., *Richmond.*
BOLTON, C. M., *Charlottesville.*
CARTER, C. D., *Charlottesville.*
DESAUSSURE, W. P. *Richmond.*
LEVY, E. C., *Richmond.*
MANVILLE, F. D., *Newport News.*
RANDOLPH, W. C. N., *Lynchburg.*
SMITH, H. L., *Norfolk.*
TALBOTT, F., *Danville.*

ASSOCIATE.

NORFOLK WATER DEPT., *Norfolk.*

WASHINGTON.—Honorary, 1; Active, 3. Total, 4.

HONORARY.

CAMERON, W. L., *Seattle.*

ACTIVE.

BECKER, G., *Seattle.*
CLARK, A., *Bellingham.*
PATERSON, A. C., *Everett.*

WISCONSIN.—Active, 9; Associate, 1. Total, 10.

ACTIVE.

BENZENBERG, G. H., *Milwaukee.*
ELLISON, B. F., *West Superior.*
HEIM, J. B., *Madison.*
MOTH, R. H., *Kenosha.*
POETSCH, C. J., *Milwaukee.*
SALMON, C. B., *Beloit.*
SANDO, W. J., *Milwaukee.*
SMITH, E. G., *Beloit.*
WHEELER, S., *Ashland.*

ASSOCIATE.

ALLIS-CHALMERS CO., *Milwaukee.*

WEST VIRGINIA.—Total, 2.

ACTIVE.

SCHWERFERGER, W., *Wheeling.*
YOUNG, F. L., *Chester.*

WYOMING.—Total, 2.

ACTIVE.

EMERY, E. L., *Rock Springs.*
PEASE, W. D., *Cheyenne.*

CANADA.—Active, 15; Associate, 1. Total, 16.

ACTIVE.

BISSETT, E. H., *Winnipeg.*
BROUGH, W. C., *Goderich.*
CHIPMAN, W., *Toronto.*
MILNE, ALEX., *St. Catherines*
PERRY, W., *Montreal.*
PITCHER, F. H., *Montreal.*

CLARK, R., *Merriton.*
DAVIS, L. H., *Salt Ste. Marie.*
FELLOWS, F. L., *Toronto.*
HEWITT, T., *Kingston.*
MOORE, J. M., *London.*
ROBERTSON, G. H., *Yarmouth.*
ROBINSON, S. C., *Walkerville.*
RUST, C. H., *Toronto.*
SCOTT, W., *Winnipeg.*

ASSOCIATE.

LONDON WATER BOARD, *London.*

FOREIGN COUNTRIES.—Honorary, 1; Active, 8. Total, 9.

HONORARY.

NAKAJIMA, Y., *Tokio, Japan.*

ACTIVE.

BLAKE, C. H. M., *Guadalajara. Mexico.*
HUMPHREYS, WM. H., *York, England.*
LAWTON, R. W., *Calcutta, India.*
SIMIN, N. P., *Moscow, Russia.*
TAUBENHEIM, N. E., *Archangle, Russia.*
TOMLINSON, S., *Singapore, S. S.*
WASTENEYS, H., *Brisbane, Queensland, Australia.*
WYNNE-ROBERTS, R. O., *Capetown, South Africa.*

ADVERTISEMENTS

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A WATER WORKS MAN WHO HAS HAD LONG EXPERIENCE IN CONSTRUCTING AND MANAGING WATER WORKS, DESIRES A POSITION WITH A CONSTRUCTING FIRM OR AS MANAGER OF A WATER WORKS. CAN GIVE EXCELLENT REFERENCES AND REFER TO WORK DONE UNDER HIS CHARGE, IN VARIOUS PARTS OF THE COUNTRY FOR FURTHER PARTICULARS ADDRESS

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14 George St.,
CHARLESTON, S. C.

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A MAN HAVING LONG EXPERIENCE AS A SALESMAN OF WATER-WORKS SUPPLIES, WHO HAS SOLD WATER WORKS APPLIANCES IN NEARLY EVERY STATE IN THE UNION, AND WHO HAS LARGE ACQUAINTANCE WITH WATER WORKS PEOPLE DESIRES A POSITION AS TRAVELING SALESMAN WITH SOME MANUFACTURER OR DEALER IN WATER WORKS SUPPLIES.

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WATER AND GAS REVIEW

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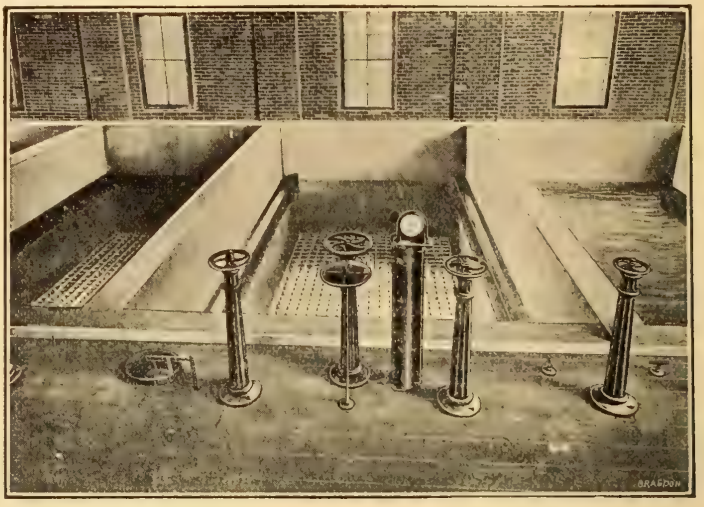

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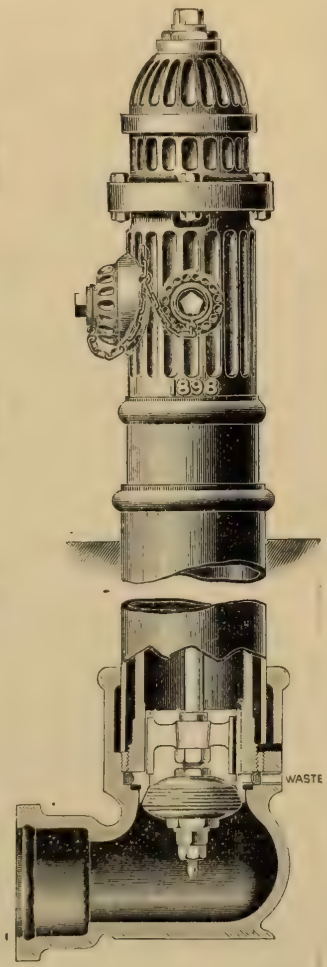

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In consideration of our entire satisfaction of the work you have done for us, we wish to attest that fact by hereby subscribing our names.

Respectfully,
(Signed) FRANK P. RICE,
Pres. Board of Water Commissioners
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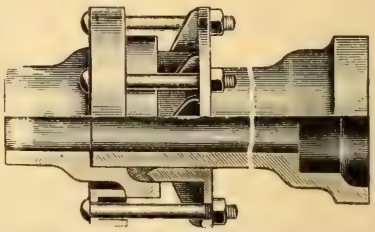

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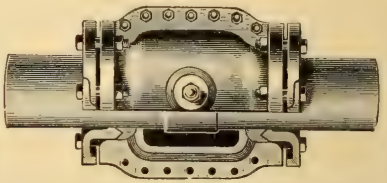

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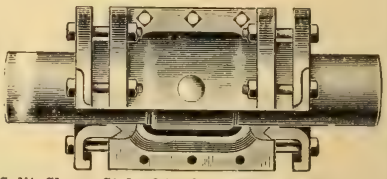
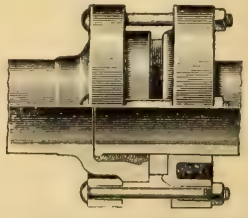


Split Sleeve Style 27, for Repairing Broken or Cracked Cast Iron Pipe.



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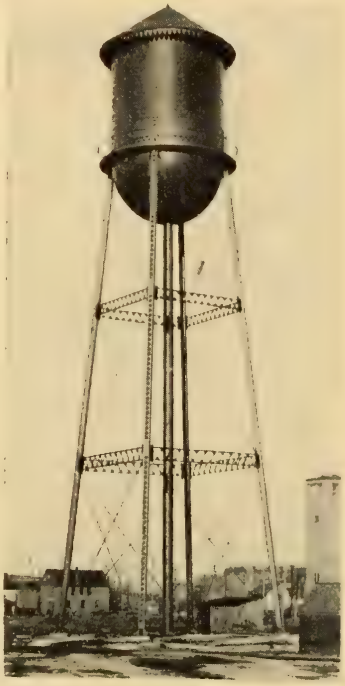

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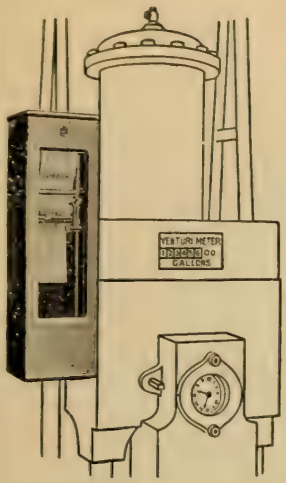

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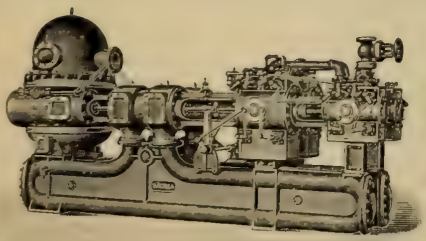

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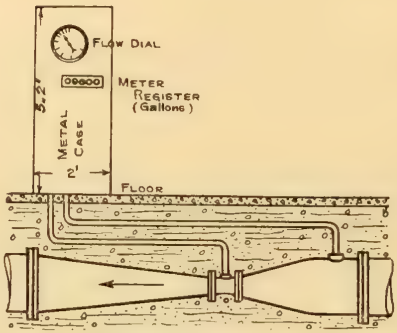
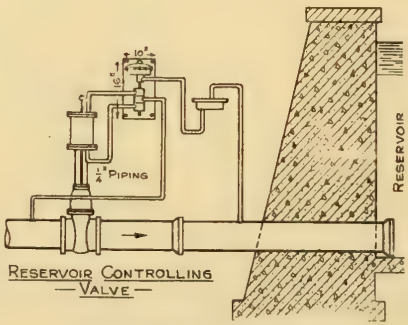


SIMPLEX METER

CONTROLLING VALVES

FOR RESERVOIRS AND STANDPIPES



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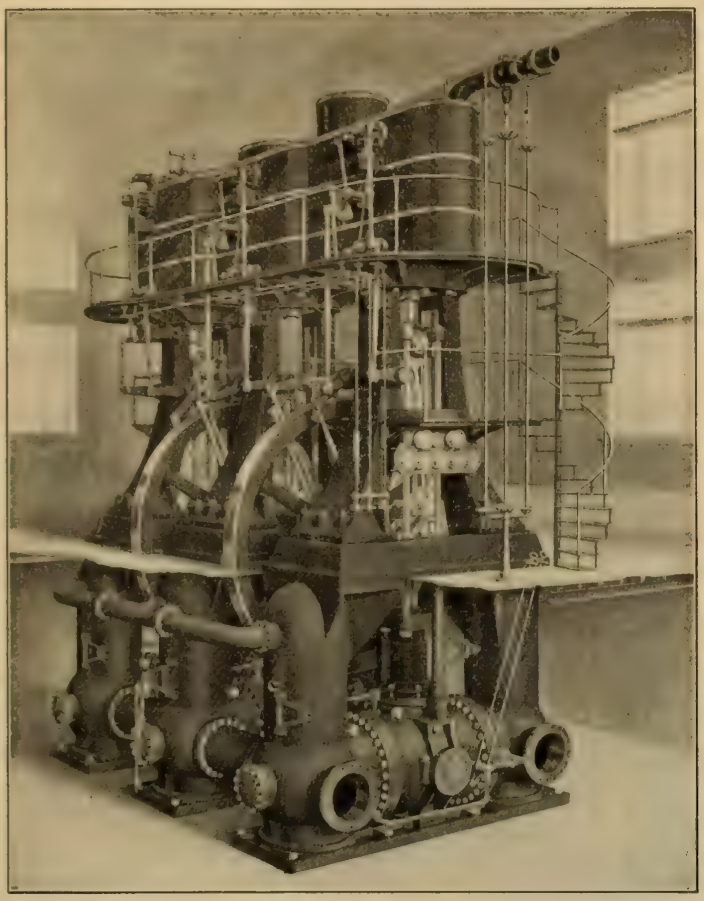
CAPACITY 10,000,000 GALLONS IN 24 HOURS.



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Centrifugal Pumps – Single and Multi-Stage Hydraulic Transmission Pumping Machinery

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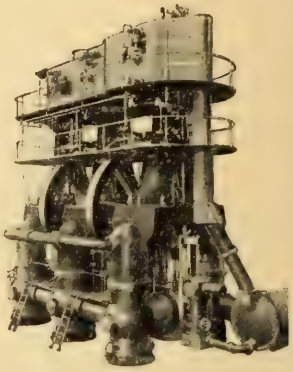
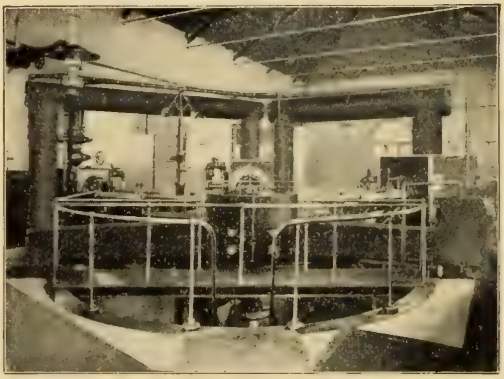


Reynolds Triple Expansion Pumping Engine recently installed at the Toronto, Ont., City Waterworks, which was built by a local firm from the designs of this company and under its supervision.



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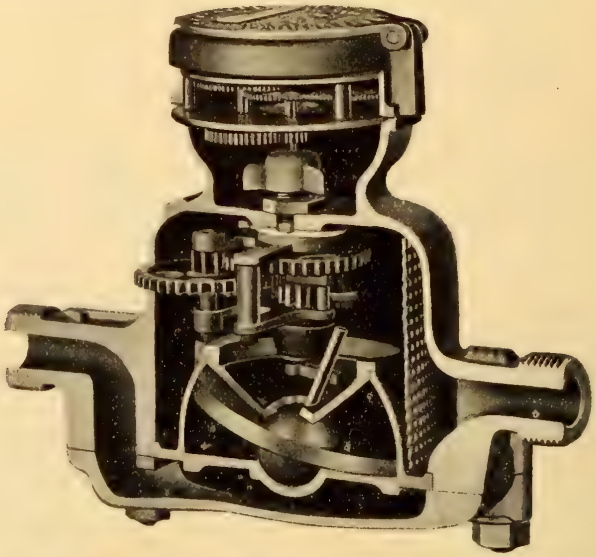

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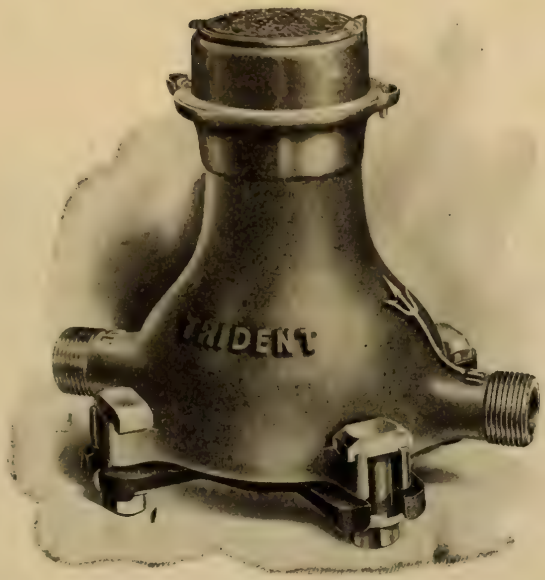

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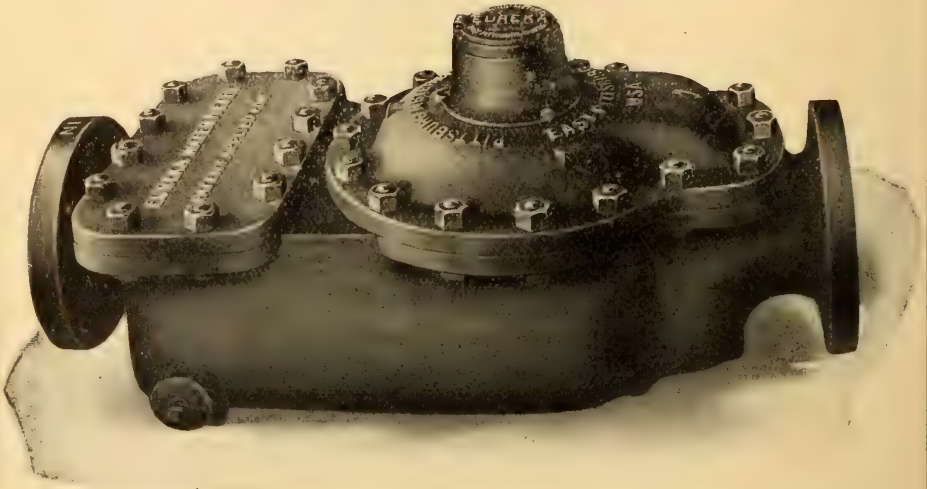

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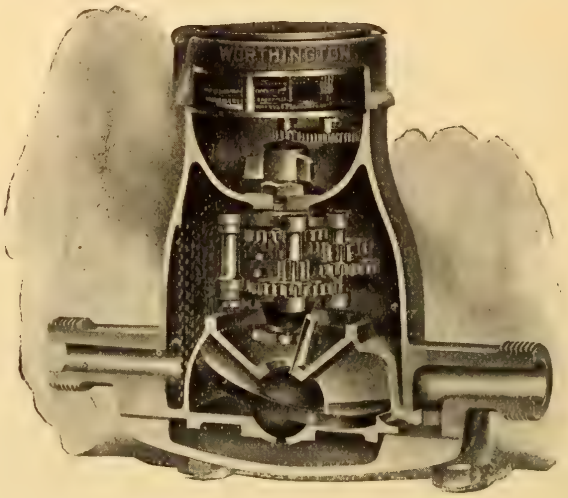
Worthington Meters



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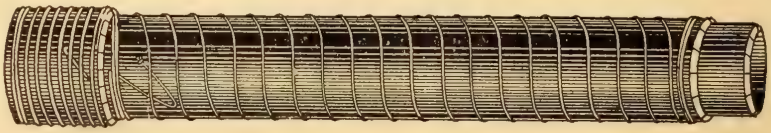

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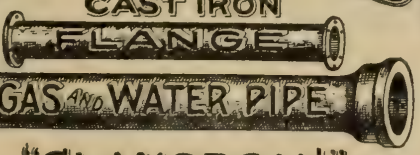

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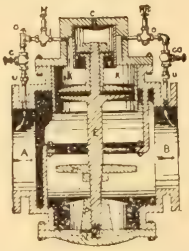

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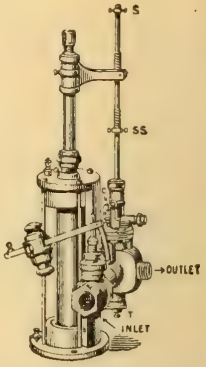

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